

**Faculty of Science and Engineering
Muresk Institute**

**Energy Requirement for Maintenance and Growth of
Bali Cattle in East Timor**

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**This thesis is presented for the Degree of
Master of Philosophy
of
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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature:

Date

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Abstract

The objective of this study was to determine the metabolisable energy (ME) requirements for maintenance and growth of Bali cattle in East Timor, using the live weight response method. The *ad libitum* water intakes of cattle eating leucaena forage were also measured.

The research was undertaken in Dili, East Timor from 25 January to 18 April 2010. Ten bulls, aged from 1.5 to 3 years and with mean live weights of 121.0 kg in Experiment 1, and 129.3 kg in Experiment 2 were confined in individual animal pens and fed two different diets: a low-quality feed consisting of mixed urea-treated rice straw and leucaena forage in Experiment 1, and a moderate-quality feed consisting of leucaena forage only in Experiment 2. The CSIRO (2007) model for *Bos indicus* cattle was used to generate preliminary estimates of the ME requirement for maintenance and the Bali bulls were fed amounts of the diets to provide 0.75, 1.0, 1.25, 1.5, 1.75 and 2.0 times the expected maintenance ME requirement in Experiment 1, and 0.85, 1.0, 1.4, 1.8 and 2.2 of this level in Experiment 2.

The ME requirement for maintenance of Bali bulls fed the low-quality roughage diet was $0.42 \text{ MJ/kgW}^{0.75}$ per day, and was $0.40 \text{ MJ/kgW}^{0.75}$ per day when fed the moderate-roughage diet. The estimated net energy requirement for maintenance, calculated as the mean of both experiments, was $0.26 \text{ MJ/kgW}^{0.75}$ per day. The ME requirement for gain was 39.2 MJ/kg and the measured kp was 13.33.

Most of the cattle in Experiment 1 lost live weight during the experiment. The urea-treated rice straw had a calculated dry matter digestibility of 38% and it was concluded that this low-quality ingredient was not suitable for growing cattle. However, all but two of the cattle fed leucaena forage in Experiment 2 gained live weight. It is concluded that leucaena forage can be used as a sole diet for growing Bali cattle, at least under the conditions applying in this experiment. The water intake in experiment 2 was 4.01 L/kg DM.

Keywords: Bali cattle, energy, maintenance, growth, water

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List of Symbols and Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ADF	acid detergent fibre
ARC	Agricultural Research Council
AOAC	Association of Official Analytical Chemistry,
BMR	basal metabolic rate
BW	body weight
CCT	Cooperative Coffee Timor
CIA	Central Intelligence Agency
%	percent
°C	degree Celsius
cm	centimetre (s)
CP	crude protein
DE	digestible energy
DM	dry matter
DMD	digestibility of dry matter
<i>et al.</i>	et alia
FAO	Food and Agriculture Organisation
Fig.	Figure
g	gram (s)
h	hour (s)
e.i.	that is
kg	kilogram (s)
kJ	kilojoules
LL	<i>Leucaena leucocephala</i>
LW	live weight
N	nitrogen
NA	not analysed
MAFF	Ministry of Agriculture, Fisheries and Food, Department of Agriculture and Fisheries
m	metre (s)
m ²	square metre (s)

ME	metabolisable energy
min	minute
mm	millimetre
N	nitrogen
NA	not analysed
NT	Northern Territory
OM	organic matter
R ²	square R
SCA	Standing Committee on Agriculture
UCT	upper critical temperature
URTRS	urea treated rice straw

1.1 Introduction

This chapter presents the background, problem statement, aim and objectives of the research. It highlights also the significance of the research, and outlines the structure of the thesis.

1.2 Background

East Timor is a developing country where agriculture has an important role in its development. Approximately 90% of the population is rural with the household farm being the most common occupation (74 %). Farming in East Timor is mixed farming consisting of livestock, crops, coffee and small food gardens. The livestock component is dominated by chickens, pigs and cattle.

Bali cattle (*Bos javanicus*) are the preferred ruminant in East Timor since these cattle are reasonably well-adapted to the harsh environment as shown by increased daily gain in wet season (230 g per day) and a high calving rate. However in the dry season, daily gain is reduced to 110-145 g per day, calf mortality is high, and the slow growth rate of young cattle results in increased time to reach slaughter weight (4-5 years).

1.3 Problem statement

Poor production performance of Bali cattle in East Timor is the result of poor management processes such as under-feeding and/or feeding of low nutritive value feed, a long dry season during which pasture becomes less digestible and loses nitrogen and phosphorus content and the sale of potentially productive animals for meat and export, thus reducing the potential number of breeding animals on farm. Approximately 60% of Bali cattle are given some form of additional feeding; the quantity, type and timing of feeding is determined by availability of the feed to the farmer rather than the nutritional needs of the cattle. Lack of information on the

nutritional (energy and protein) requirements of Bali cattle for maintenance and growth means that there is limited information on potential feeding systems available for farmers.

1.4 Research aim

Given the stated problems, the aim of the study is to determine energy requirements of Bali cattle for maintenance and growth using available feed resources. It is envisaged that this information can be used to assist extension providers to enable farmers to make more informed decisions on the planning and implementation of Bali cattle production systems in East Timor.

1.5 Objectives of the study

The objectives of this study were to:

1. To determine the metabolisable energy requirements for maintenance and growth of Bali cattle in East Timor.
2. Contribute to improving cattle productivity of East Timor.

1.6 Significance of the study

This study will provide information on:

1. the digestible and metabolisable energy requirement of growing Bali cattle
2. methods to estimate live weight gain on farm
3. information to calculate the daily quantity of feed needed for growing Bali cattle
4. methods of improving the performance of Bali cattle in East Timor through improved feeding practices

2.1. Introduction

Cattle production systems are influenced by environmental conditions. In the tropics seasons are characterised as either 'wet' or 'dry'. Performance cycles in a tropical environment are characterised by decreased level of production during the dry season due to insufficient quality and quantity of available feed. The provision of adequate levels of nutrients from pastures to livestock is a major problem in tropical areas. Jelantik (2001) found that the availability of grass in pastures in West Timor (Indonesia) fluctuated greatly. During the dry season cattle production may be limited by low crude protein levels (CP) as well as low feed digestibility of pastures, as indicated by high crude fibre (CF) levels.

Bali cattle are the dominant ruminant in East Timor. Level of productivity of cattle is influenced by climate, presenting East Timor farmers with many challenges. The dry season is longer– this has a major influence on both quality and quantity of feed available to livestock. Data show that cattle breeds in the tropics demonstrate a large range in productivity with reasons for those differences not having been clearly defined. Comparative studies of total-tract digestibility using a variety of diets and range of intakes failed to provide clear evidence that any one breed was superior to another with respect to feed digestibility (Moran and Vercoe 1972). However, it might be expected that tropical breeds would be able to perform well in the conditions when offered a diet containing an adequate supply of nutrients. Energy can be considered the most limiting nutrient in the tropics followed by protein, minerals and vitamins.

This literature review will focus on energy requirements of Bali cattle with particular emphasis on factors associated with tropical climate and the impacts of these factors on tropical cattle production systems in East Timor.

2.2 . Tropical climate and its impacts on animal production

2.2.1. Tropical climate

World climate regions, using the Köppen Climate Classification System, are classified based on the annual and monthly averages of temperature and precipitation (Ritter, 2006). Factors that influence world climate regions include altitude, pattern of prevailing winds, distribution of land and seas, distribution of barriers, position of high and low pressure zones, heat exchange from ocean currents, air mass influence and latitude and its influence on solar radiation received. According to the Köppen Climate Classification System, the five main world climate regions are tropical climate, dry climate, moist subtropical mid-latitude climates, continental climate and polar climate.

Tropical climate is a non-arid climate with average temperatures above 18°C and annual precipitation greater than 1500 mm (Keefer, 2000; Ritter, 2006). The tropical climates extend northward and southward from the equator to about 15° to 25° of latitude respectively. The equatorial belt experiences tropical climate usually marked with hot and humid conditions (Ritter, 2006). High rates of evaporation and rain formation are a consequence of high levels of sunlight; the daytime temperature in this region is usually greater than 35°C with night temperatures around 22°C (Ritter, 2006).

2.2.2. Climate of East Timor

East Timor experiences a tropical climate with a monsoonal rainfall pattern. This produces two distinct rainfall patterns: northern monomodal rainfall patterns produce a 4-6 month wet season beginning in December which affects most of the northern side of the country and tapers to the East; and the southern bimodal rainfall pattern produces a longer (7-9 month) wet season with two rainfall peaks starting in December and again in May; this pattern affects the southern side of the country (Keefer 2000). The level of precipitation can be characterised as being low to very low along the northern coast of East Timor (<1000mm/annum), low to moderate throughout the central and elevated areas (1500-2000mm/annum), and relatively

high (>2500mm/annum) in high altitude areas which are mostly in the west. In common with most tropical locations, extremely heavy rainfalls may occur in East Timor during relatively short time intervals.

As is characteristic of the tropics, temperature variation from month to month is minimal in East Timor. Keefer (2000) reports that mean temperature at any given place monthly varies by 3°C or less between the coolest months of July and August to the warmest months of October and November. Differences between daily maximum and minimum temperatures range from 7°C to 13°C (Keefer 2000). The greatest temperature differences occur with increasing altitude. Temperature decreases with altitude - for example in Mubessi, which is 1,400 metres above sea level, the mean monthly temperature is approximately 17°C in July and 24°C in November, compared with Liquica which is 25 m above sea-level where the mean monthly temperature is approximately 25°C in August and 31°C in February (Keefer, 2000).

2.2.3. Direct effects of weather on animal production

Weather and climate influence animal performance in terms of survival, growth, reproduction, milk and wool production. Potential environment stressors include high or low ambient temperature, high humidity, high or low thermal radiation and high wind speed. These can directly and adversely affect animal performance, health and well-being when coping capabilities of the animals are exceeded (Da Silva *et al.*, 2002).

High humidity and/or high solar radiations increase the effect of high temperature on livestock. High humidity reduces the potential for skin and respiratory evaporation by the animal thus reducing the animal's ability to maintain core temperature. High temperature may affect feed intake, while solar radiation adds to the heat from metabolic processes which must be dissipated to maintain body temperature (Da Silva *et al.* 2002).

The characteristics of the outer surface of an animal's body are of great importance in the regulation of the animal's core body temperature relative to its ambient environment. Animals in tropical regions need to be able to dissipate excess heat

through the skin and from the respiratory surfaces, while minimising the input of thermal energy from the environment. The degree to which this is achieved is dependent on protective properties of their body. Such protective properties depend on the morphological characteristics of the skin (colour, thickness, sweat glands) and of the hair coat (especially the thickness of the coat, number of hairs per unit area, diameter of the hairs, length of the hairs, and angle of the hairs to the skin surface), which allow the animal to exchange heat with the environment. Respiratory heat loss by evaporation seems to be of some importance in tropical environments; experiments with Holstein cattle in temperatures between 10°C and 36°C demonstrated that heat loss by thermal radiation decreases from 160 to -30 W m⁻², while the latent heat loss by evaporation increases from 30 to 350 W.m⁻² (Maia *et al.* 2005). At ambient temperatures greater than 30°C, evaporative heat loss is the main route for temperature control. Similar results were shown by Da Silva *et al.* (2002) in sheep.

2.2.4. Impacts of climate on feed supply and feed quality

All aspects of animal production are influenced by this climate. In the dry summers and in the tropical dry winters when the plant growth has slowed, the diet of the grazing animal is made up of mature plant material that is low in quality (Hogan 1996). As a result the ability of the animal to gain nutrients from the diet is restricted, not only by the presence of plant fibre that is resistant to microbial attack, but also by the decline in content of both protein and minerals; intake levels can be considered inadequate for both fermentative microbes and the tissue requirements of the animal (Hogan 1996).

Tropical grasses are relatively low in digestible dry matter, energy and protein and high in fibre content compared with species in temperate zones. These differences result from more rapid physiological growth and early maturation of tropical species, particularly C4 tropical grasses. The major influence in this difference is the anatomy of these grasses compared to the anatomy of C3 (temperate) grasses. Temperature and light have a major influence on the growth pattern (Devendra and Gohl 1970; Stobbs 1971). As a result of these differences in anatomy and growth patterns, tropical pastures are less palatable and lower in digestibility than temperate pastures.

Palatability and intake decrease with lower quality forages (Parish and Rhinehart 2008)

Lower digestibility of tropical forages is reflected in different lengths of time for digestion, as well as by processing and chemical treatment. As plants mature, cell walls become more lignified due to high ambient temperature and less digestible. Tropical forages are often too mature at cutting or grazing, which is linked to major decline in forage digestibility (Parish and Rhinehart 2008). In general it is rarely possible to achieve a dry matter digestibility level of over 70% for tropical forages.

2.3. Tropical cattle production systems

2.3.1. Approaches to cattle production in the tropics

Cattle production systems in tropical countries vary widely. Farmers need to develop practices to resolve the problem of insufficient feed that occurs during the dry season in many tropical countries, including East Timor.

Feed practices are integrated with cropping in order to maximize productivity of the small farm areas. In Lombok, Indonesia, a simple and practical method of overcoming the low reproduction rate of Bali cattle in mixed crop-livestock system has been widely adopted (ACIAR 2003). The ACIAR project demonstrated the potential success of twin strategies of controlled mating (one bull, 3 months mating period) and weaning calves at 6 months. Application of this approach resulted in cows in better condition that were less costly to feed, and calves growing better due to better feeding strategies.

Secondly, due to a prolonged dry season such as in the North Luzon region of Philippines, problems include lack of green grass (quality feed) during a large part of the dry season and a lack of quantity of roughage (Lemcke 1993). To cope with these problems, there are several strategies that could be applied. These include planting of improved pastures which are saved for use in the dry season, conservation of rice stubble as roughage, conservation of fodder during the wet season as silage for use in the dry season and the use of sugar cane plus tops for use

as potential feed resources for cattle. These feeds can be used in a cut and carry system that is commonly used in small farms such as in East Timor.

Thirdly, pasture degeneration through over-grazing is a potential problem for East Timor cattle owners. This type of problem has been noted in northern Australian (Lemcke 1993) where it was caused by increasing annual pasture intake per head without reducing stocking rate.

Nutrient supplementation has been widely used throughout the Northern Territory for many years as a means of overcoming some of these pastures deficiencies. Methods of supplementation have included the use of lick blocks, loose (dry) mixes and, to a lesser extent over the past twenty or more years, water-based supplementation (Hill 1988). Native pastures in the Northern Territory have been recorded as having low digestibility, and deficiencies in nitrogen (N), phosphorus (P), and sodium (Na) for most of the year, with a deficiency in sulphur (S) in the dry season (Andison 1994).

2.3.2. Husbandry and management methods

Farms in East Timor are characterised by small flock size with low levels of production. Small ruminants survive mainly by foraging crops and pastures in and around villages, wastelands, irrigation banks, roadsides or crop areas. The same situation occurs in Malaysia (Devendra 1983) where low level of productivity is due to the limited availability land since available land is usually prioritized for crop cultivation.

To resolve the problem the integrated or zero land livestock production system has been developed (Devendra 1983); this system has been designed to aid in the development of the livestock industry without having to utilise new land for pasture production. Feed resources could then be made available at a lower cost than the conventional, monoculture animal-production system. These potential feed resources can be categorized as undergrowth, cultivated pastures and agro-byproducts (Reza 1998).

In Nusa Tenggara, western Indonesia, farmers manage their cattle in one of four ways: (i) animals are individually housed and hand fed; (ii) animals are tied to a tree

during the day and housed at night; (iii) animals grazed during the day and housed at night; and (iv) animals grazed freely day and night. This translates into two main management categories: (i) semi-intensive, in which farmers have close contact with their animals; and (ii) extensive, in which the animals are mostly left to graze freely with very little intervention by the farmers. The preferred system in Nusa Tenggara is to tie cattle under a tree during the day and stable cattle only at night. In West Timor only 2.1% of farmers housed cattle at all times. The traditionally preferred management system is not to house cattle and to utilize as much as possible grazing resources rather than cut-and-carry systems (which require more labour), particularly if animals are housed day and night and stall fed (ACIAR 2003).

2.3.3. Cattle production system in East Timor

Livestock production in East Timor occurs mainly under a household farm system. Over 60% of households in East Timor are involved in some form of animal husbandry (Hofmann 2000). The dominant species of livestock are chickens, pigs and cattle. Bali cattle (*Bos javanicus*) are the dominant ruminant species (42% in 2002), white water buffalo (26%) and goats (2%) make up the other species (MAFF 2006).

East Timor has both native and introduced pastures (Da Cruz 2003). Da Cruz (2003) reports that there are 206,000 hectares of grazing land in East Timor within four districts; the largest areas of grazing land are Lautem, Covalima, Manufahi, and Viqueque (main urban centres: Los Palos, Suai, Same and Viqueque).

There are large areas of native unimproved pasture in localities such as Viqueque that are heavily grazed by cattle; however approximately 50% of the area is comprised of the weed chromolaena (MAFF 2006), considered to be a major threat to pastures as an invasive species in many tropical countries.

Pastures have been improved through the planting of forage species. These include both legumes (*Leucaena leucocephala*, *Gliricidia*, *Sesbania grandiflora*) and grasses (*Pennisetum purpureum*, *Panicum maximum*) (MAFF 2006). In the Same district MAFF successfully established a fodder bank of 2–3 hectares. However, it was not well used by farmers due to the lack of farmer interest and unfamiliarity with the

system. Similarly, in Lospalos, forage was well established but poorly utilized by farmers. Moreover, poor management resulted in the legume becoming less nutritious; infrequent cutting resulted in the fodder source decreasing in quality. *Leucaena* has grown well, but in August 2004 the other two legume species were not thriving and were sparsely covered in the leafy material that would be suitable for browsing or cutting.

Leucaena leucocephala is one of the most productive and versatile multi-purpose tree legumes for the tropics. In East Timor leucaena is available all year. Its main use is as feed for ruminants but it also is used to increase soil fertility through the fixation of nitrogen. Shelton (1998) found that it was the most suitable forage species for use in both extensive grazing systems and cut and carry system for smallholders, and that it improved soil fertility and stabilized degraded lands. As a source of energy leucaena is highly digestible. Chuzaeni and Soejono (1987) reported that the chemical composition of leucaena is: dry matter (DM) 88%, crude protein (CP) 24%, ether extract (EE) 2%, crude fibre (CF) 20%, ash 10% and organic matter (OM) 90%. It is highly regarded as a productive tropical legume based on its ability to generate high rates of live weight gain (Jones 1994). Leucaena contains high levels of critical nutrients, including energy and protein and could be utilised to increase productivity of Bali cattle in East Timor, especially during the dry season when availability of other feed is limited.

It is unlikely that East Timor will successfully develop any livestock industries based on the feeding of concentrate feeds that are derived from cereals as these are required for human consumption. East Timor has a problem feeding its people with adequate cereal and rice production; therefore, the diversion of these resources to cattle is not a viable option (MAFF 2006). As a consequence improved feeding management can only be achieved through improved pasture, utilisation of forage crops and/or utilisation of by-products from cropping.

By-products from crops grown in East Timor include rice straw (currently burned), rice bran, maize stalks and leaves, maize cobs (after removal of the grain) and the vines of leguminous crops such as peas and beans. Although these by-products are of low commercial value, they can be used at the village level for feeding livestock.

Palatability and protein content of these can be improved by using amino acid additives (expensive), the addition of urea, and where available molasses (palatability and energy). The only source of molasses in the region is Java – cost of import may limit its availability and use. Making better use of existing by-products for village level cattle fattening needs to be investigated and farmers trained to make use of these by-products.

There are three traditional cattle rearing systems used in East Timor. Firstly, the cattle may be kept or tied in a very simple stable with a soil floor and a roof of iron sheets or dried grass/straw. Commonly all the calves, heifers and cows are kept together in the same place and the cattle are fed the grass twice a day, in the morning and in the late afternoon. The fattening steers are kept separately and receive better quality grass, usually with added concentrate.

Secondly, all cattle except the fattening steers are kept and tied in the grass area for an extended time especially during the dry season (3-4 months). Cattle eat the grass *ad libitum*. The farmers will check the cattle regularly and move them to other areas as required.

Thirdly, farmers might use a combination of both production systems. The cattle are kept and tied in the pasture throughout the day for grazing and moved into the stable at night.

2.3.4. Bali cattle in East Timor

Bali cattle (*Bos javanicus*) in East Timor are typically small. Females have an adult live weight of 224-300 kg and are around 1.05–1.14 m high, while adult males have a live weight of 337-494 kg with a height of around 1.22–1.30 m (Pane 1991). In comparison, the live weight of the best Bali cattle at a livestock exhibition in 1991 in Indonesia was 450–647 kg with a height of around 1.25–1.44 m (Harjosubroto 1994).

Bali cattle are recognised for their potential fertility and production performance even under poor environmental conditions (Soebandriyo and Handiwirawan 2002). Calving rate of Bali cattle is variable with the average calving rate in Indonesia being 83% (Wirdahayati 1994) stating that the rate ranged from 75-90% while calving rate

of Ongole cattle (Zebu type) was only 35%. In another study with Bali and Ongole cattle carried out on a few major islands in Nusa Tenggara in which cattle production was intensively monitored for three years (1990-1993), Wirdahayati (1994) found that the average calving rate for Bali cattle was again higher than for Ongole cattle (62% vs. 41%).

In East Timor, the cattle herds are generally quite small, with only 3-4 cattle per family. The male calves are usually kept for fattening. They are needed to supply the local market and to be exported to Indonesia. The female calves are for breeding purposes, to maintain the balance of cattle production.

Bali cattle reach puberty at 20-24 months for females and 24-28 months for males and have a relatively high conception rate (86%) (Subandriyo and Handiwirawan 2002). Bali cattle have high carcass dressing percentage (52–57.7%) (Rollinson and Payne 1973) compared to Ongole and Madura cattle (52 and 53% respectively) (Arka 1996). They have a good meat score for organoleptic acceptance (colour, texture, flavour and taste) (Mastika 2003) with low fat content (approximately 4%), (Payne and Hodges, 1997).

Low productivity of Bali cattle affects the culture and sustainability of farmers in East Timor. Traditional farmers prefer to utilise grazing resources due to lack of a financial incentive to invest in the labour required for other systems. Utilising available grazing areas provides a cheap source of feed for production (da Cruz 2003). Farmers might utilise a night-pen for security and may guard the animals with the farmers taking turns to sleep with the cattle next to the fenced-in area (MAFF 2006). Others graze the animals on pastures, with little restriction or tethering; cattle may be penned periodically after one or two days grazing (da Cruz 2003). MAFF (2006) reported that both cell grazing systems (which required labour more) and rotational grazing systems are not familiar to all farmers; farmers are therefore reluctant to accept those systems.

Generally, in East Timor the farmers prefer the traditional production system which has little or no supplementation (FAO 2003). However, nutritional supplement is required to ensure that the nutrient requirement of cattle is met, particularly during the dry season. Jelantik (2001) found that the daily gain of Bali cattle fed rice bran as

a supplement (60%) decreased with advancing dry season (241 g/day to 145 g/day for cows aged two and eight months respectively). Wirdahayati and Bamualim (1990) found that during the dry season Bali cattle of all ages lose weight; calves less than one year old lost 150-220 g/head/day, young steers 340-350 g/head/day while late in dry season mature bulls and cows might experience more severe weight loss (420-520 g/head/day). A study by Fattah (1998) reported that about half of Bali calves born on native pasture in Nusa Tenggara during dry season died before one year of age. Calf mortality of Bali cattle is high (30%); mating and conception occur during the rainy season resulting in calving during the dry season. Poor quality feed reduces the milk supply to the calves (Toelihere 2003). Calves that survive often have a low growth rate during the season - this may result in long term effects such as delayed age at puberty (Wirdahayati 1994).

Another factor that contributes to low productivity of Bali cattle in East Timor is the selection of cattle for export and slaughter; many potential breeders (female and male) are sold. There is a tendency by farmers to sell the best bulls and keep poorer animals for breeding; this leads to a gradual decline performance of the herd and a reduction in mature animal size (MAFF 2006). In Indonesia similar practices result in the best bulls being housed as fattening cattle for export and poorer cattle used for breeding.

2.3.5. Bali cattle raised under poor conditions

Bali cattle are well-adapt to poor conditions such as poor nutrition and low level of management (Wirdahayati and Bamualim 1990). A survey on the productivity of Bali cattle grazing in Nusa Tenggara under the existing conditions and the effect of season on cattle productivity was conducted by Wirdahayati and Bamualim (1990); Bali cattle perform well in both wet and semi-arid tropical areas (Wiryosuharto 1996; Entwistle *et al.* 2001).

Although Bali cattle have possible advantages in these conditions, production is limited by a number of factors. These include slow growth of calves and weaners increasing the time to reach a saleable age (Panjaitan *et al.* 2003; Kusumaningsih 2002); high calf mortality, averaging 7% up to 6 months age (Sumbung 1977;

Darmaja 1980). Copland *et al.* (2003) identified constraints to cattle production in East Timor - low reproduction rate expressed as low calving percentage, long inter-calving interval, low weaning percentage, low milk production, high mortality in calves, slow growth rate in young cattle, damaged and degraded land through overgrazing and invasion of weed, poor quality grasses, and diseases such as brucellosis and haemorrhagic septicaemia. The study did not present statistics of each constraint, but concluded that they were due to environmental effects and poor nutrition during the long dry season. Therefore, a more focused study on feed requirements was considered necessary.

2.4. Nutrient requirements of cattle

Feed contains proteins, carbohydrates, fats, vitamins, minerals and water that are the basic nutrients required for all animals. Nutrition is a key to levels of cattle reproduction, cow and calf health, and growth of all classes of cattle (Marston 2008). The level of each nutrient required is influenced by the age of animal, its level of productivity, and the type of product being produced (draught work, muscle/bone/fat, milk) (Church and Pond 1988; Dryden, 2008). Nutrient requirements of cattle change throughout the year based upon stage of the production cycle, age, sex, and breed, level of activity, pest load, and environment (Hersom 2007). Therefore, nutrient requirements are dynamic. Environmental and production factors may change rapidly over a short period of time, resulting in major changes for nutrients (Marston 2008). Requirements for energy are the most variable, followed by the protein, mineral and vitamins. Nutrient requirements are influenced by level of production (Dryden 2008; Marston 2008). Nutrient requirements need to be understood both for maintenance and for the required level of production in order to meet production objectives (Dryden, 2008).

2.4.1. Energy requirement

Energy is a critical factor in every biological system. Energy is required for functions of the body such synthesis of specific molecules (enzyme and hormones), to drive anabolic reactions or to develop the body's reserves (McDonald *et al.* 2002). Hennessy (1980) reported that the availability of energy has a major influence on

microbial growth in the rumen. The microorganisms in the rumen have ability to provide microbial protein and energy to the animal by obtaining energy from feed fibre components for microbial growth (Dryden 2008) and through the production of volatile fatty acids (VFA's) (typically acetic, propionic, and butyric acids) (Russel and Gahr 2000, Dryden 2008). VFAs provide important fuel for ruminants (60-80%) of total energy (Dryden 2008). Ruminants are dependent on gluconeogenesis for maintaining blood glucose concentrations (Russel and Gahr 2000).

The efficiency of energy utilisation depends largely on the energetic efficiency of the metabolic pathways involved in the synthesis of fat and protein from absorbed nutrients. The value to be placed on protein as a source of energy for productive purposes is of importance in any assessment of the nutritive value of diets. Ruminant animals produce about 60% more heat than do non-ruminants when the metabolisable energy of protein is used to synthesize fat (Blaxter and Martin 1962). When the protein content of forage is inadequate, feed intake drops and the digestibility of energy is reduced (Campling *et al.*, 1962). Dryden (2008) indicated that decreased intake is associated with inadequate supply of energy to the organism resulting in decreased production of microbial protein. Microbial growth is sufficient when the ingested forage contained more than 25 g N kg⁻¹ DOM (Egan 1976).

Parish and Rhinehart (2008) stated that energy requirement will vary with stage of production, size the animal and the required level of production. The total amount of energy needed by any animal is the sum of the maintenance energy requirement ('non-productive') and the energy required for production (weight gain, reproduction milk production) (Marston 2008). Net energy requirement for gain is not a function of body weight or surface area but rather a consequence of feed quality, rate of gain and the composition of the growth.

2.4.2. Energy for maintenance

The energy requirement for maintenance is defined as the metabolisable energy (ME) intake per day at which the animal is in zero energy balance (Dawson and Steen 1998) or the ME intake which keeps the animal at a constant body weight and composition (Dryden 2008). Metabolisable energy (ME) can be estimated as total

(gross) energy intake minus faecal energy (FE), urinary energy (UE), and gaseous energy (GE) losses (NRC 2000). Jessop (2004) stated that energy costs for maintenance can be considered quantitatively the most important – over the lifetime of an animal maintenance energy requirements account for 98% of total energy needs. Even in animals slaughtered before they reach maturity, maintenance cost can be around 50% of total nutrient requirements.

2.4.3. Maintenance includes many functions.

Firstly, the basal metabolism rate (BMR) or minimal metabolic rate is the animal's basic life-sustaining function. The main role of energy is to maintain cell function within the animal, and ensure minimal activities such as respiration and circulation enabling the animal to survive (Jessop 2004). This represents the amount of energy used each day for these basic functions and it is the lowest rate at which the normally nourished animal uses energy (Dryden 2008). The energy used is represented as the total of the heat production in a rested animal in the post-absorptive state i.e. when there is minimal processing of food within the digestive tract (Jessop 2004).

Maintenance energy is also required for muscular activity including involuntary muscle action such as beating of the heart as well as animal movement and muscular activity associated with eating and processing of food within the digestive tract. Maintenance energy is also used for operation of the immune system and fighting infection, as well as being utilised for thermoregulation, depending on environmental factors (Jessop 2004).

Maintenance energy requirement varies with body weight, genotype, sex, age, season, temperature and physiological status (NRC 2000). Energy required for maintenance for beef cattle have been estimated as $0.322 \text{ MJ/W}^{0.75}$ per day where body weight (W) is kilograms (NRC 2000). The NRC (2000) publication gives ways of allowing for the effects of ambient temperature, season, age, physiological state, on the ME_m . The calculation of requirement of ME for maintenance by SCA (1990) is:

$$NE_m = k \times s \times m [0.28W^{0.75} \times e^{(-0.03A)}] + 0.1NEI + EGRAZE + ECOLD.$$

where: NE_m = NE for maintenance (MJ/d); k, s, m = factors which modify calculated value of NE_m to take account of animal species and breed, sex (either entire male or not) and the proportion of milk in the diet (these values vary between 1 and 1.4, 1 and 1.5, and 1 and 1.23); $W^{0.75}$ = metabolic size (kg); A = age (years, to a maximum of 6); NEI = net energy intake (MJ/d); EGRAZE = net energy used in activity associated with grazing (MJ/d); ECOLD = net energy needed to maintain internal body temperature in cold conditions (MJ/d).

This equation takes into consideration factors such as breed, sex, and proportion of milk in the diet. Age (A) is stated as years with a maximum value of 6; NEI is net energy intake (MJ/day). EGRAZE is net energy used in activity associated with grazing (MJ/day) and ECOLD is net energy needed to maintain internal body temperature in cold condition. Metabolisable energy for maintenance is calculated using an efficiency coefficient (k_m), calculated as $0.02 M/D + 0.5$.

Most reports comparing breeds conclude that there are differences in maintenance energy requirements between these breeds. A consequence of the diversity of breeds and different methodologies, it is difficult to generalise about maintenance energy requirements. The *Bos indicus* breed of cattle requires about 10 percent less energy than traditional beef breeds (*Bos taurus*) of cattle for maintenance, with cross breeds being intermediate (NRC 2000). There is evidence that animals with the genetic potential for high-productivity will be disadvantaged when faced with nutritional and/or environmental restrictions (NRC 2000). There are reports that show the correlated responses of selection for growth are influenced by a genotype/environment interaction; some animals may be highly adapted to a specific environment but less adapted to different environments and therefore have decreased adaptability to environment changes (Frisch and Vercoe 1984). Unfortunately, there are no references available for maintenance energy requirement for Bali cattle due to lack of research on this breed.

There is little difference in fasting heat production or metabolisable energy requirement for maintenance between sexes. ARC (1980) and CSIRO (2007) report that fasting metabolism of castrate males and heifers is similar. Estimated ME requirements for Hereford bulls and heifers show a difference of only 2%; however, overall, the males animal have higher energy requirement than females (NRC 2000).

In cattle and sheep there is evidence that young animals have a higher fasting metabolism than adult animals (ARC 1980). Graham *et al.* (1974) stated that maintenance energy requirements decrease exponentially and are related to age by the relationship $e^{-0.08\text{age}}$; this results in a decreased ME requirement ranging between 3 and 8 per cent per year (CSIRO 2007; NRC 2000). ME requirement of mature, productive cows is less than that of younger, growing animals post weaning (NRC 2000).

Seasonal effects on maintenance energy requirements are associated with the effect of temperature on the metabolism of cattle and sheep. Heat production of cattle is a result of tissue metabolism and fermentation in the digestive tract (NRC 2000). Heat production (HE) is related to feed intake and efficiency of energy use; body temperature control is primarily via regulation of heat dissipation. When effective ambient temperature increases above the zone of thermo neutrality and is higher than the upper critical temperature (UCT) productivity will decrease, primarily as a result of reduced feed intake. In cold conditions, animal metabolic rate must increase to provide adequate heat to maintain body temperature and the energy requirements for maintenance increase (NRC 2000).

Physiological state has an impact on the energy requirement for maintenance. The maintenance requirement of lactating cows is more than 30 percent higher than non-lactating cows (NRC 2000). Few data are available regarding efficiency of use of ME for muscular work. Grazing cattle walk considerably further than penned animals and, therefore, expend more energy for work; however, the extent to which grazing animals expend more energy standing, changing positions, eating, or ruminating than penned cattle is not well documented (NRC 2000). It is recognised that energy expenditure for work by grazing cattle is influenced by many factors including herbage quality and availability, topography, weather, distribution of

water, genotype, or interactions among these factors. Variation among individuals may be substantial.

The amount of energy could be predicted from information on the amount and chemical composition of product (milk, body tissue, maintenance or pregnancy) (Dryden 2008). When growing animals are storing energy in the form of protein and fat it is possible to calculate, by the mathematical procedure known as regression analysis, the energy used for each of these processes (McDonald *et al.* 2002). The NRC (2000) lists three methods that can be used to measure maintenance energy requirements; (i) long term feeding trials to determine the quantity of feed required to maintain body weight, (ii) calorimetric method and (iii) comparative slaughter.

Long term feeding trials can be used to estimate the quantity of feed required for maintenance – the trials use large numbers of cattle (NRC 2000). This system is suitable for the measurement of maintenance energy requirement for mature, non-pregnant, non-lactating cattle (Laurentz *et al.* 1991); however, the same method is problematic with growing, pregnant, or lactating cattle due to changes in body composition and composition of weight change (NRC, 2000). Calorimetric methods can be used to measure fasting heat production (FHP) plus urinary energy lost during the same period therefore providing a measure of fasting metabolism (FM). Animals which are fed a specified diet for 3 weeks are trained to the calorimeter and kept in a thermo neutral environment. Measurements are usually made during the third and fourth day after withdrawal of feed. For practical use, the FM value is adjusted for the difference between fasted weight of animal and its live weight when fed by adding an activity allowance of 1 KJ/kg live weight for cattle (NRC 2000).

The slaughter procedure can be used to measure maintenance energy requirement directly through measurement of RE (retained energy) and the HE (heat production) (NRC 2000). RE is measured as the change in body energy content of animals fed at two or more levels of intake (one of which approximates maintenance) during a feeding period. RE equates, by the definition, to NE_g (net energy for gain) in a growing animal. The slope of the linear regression of RE on ME intake provides an estimate of efficiency of utilization of ME for growth (k_g). The ME intake at which $RE = 0$ provides an estimate of ME requirement for maintenance (ME_m). By

convention, the intercept of the regression of log HE in ME intake is used to calculate an estimate of FHP, which equates to NE_m. The efficiency of utilization ME for maintenance (k_m) is calculated as the ratio of NE_m to ME_m. These approaches have an advantage over calorimetric methods because they allow the experiments to be conducted under situations more similar to those found in the beef cattle industry. In order to more accurately assess the body energy changes, accurate estimation of body composition both at the beginning and at the end of the feeding period is required (NRC 2000).

2.4.4. Energy requirements for growth in cattle

Net energy for gain is defined as the energy content of the tissues deposited, which is a function of the proportion of fat and protein in the empty body tissue gain (NRC 2000). Net energy is net energy value of feed after deducting the heat increment which not only for maintenance but for various form of production such as growth and fattening, for milk, egg or wool (McDonald *et al.* 2002). Once the energy requirements for maintenance are met, the remaining energy can be utilized for production such as body weight gain (Rush 1997; Hersom 2007); the energy composition of the product depends on the product composition (Dryden 2008).

An accurate calculation of energy requirement is essential in order to ensure that the level of production measured is the same as the production goal and/or the genetic potential. The SCA (1990) equation for predicting the NE requirement for a particular growth rate is

$$NE_g = LWG \times \{(6.7 + R) + (20.3 - R) / [1 + e^{(-6)}]\}.$$

The equation is suited to all types of cattle except large European breeds. The LWG is growth rate measured in kg/day; R is adjustment for weight gain or loss (= [(EBC)/(4 SRW^{0.75})]-1; EBC = empty body weight change (g/day) (or 0.92LWG); SRW is standard reference weight for the breed (kg) and P is current W/SRW.

The equation for k_g varies with the quality of feed; for all forages is

$$k_g = 0.63 M/D - 0.308 \text{ (CSIRO 2007)}.$$

2.4.5. Protein requirements for growth in cattle

Protein has many essential functions in cattle such as enzymes, muscles, nerves and soft tissues. Metabolism and growth depend on the availability of protein and nitrogen is constantly required by the animal due to secretion into digestive tract, or as detritus, synthesis of amino acids and enzymes) (Dryden 2008). Deficiency of protein in cattle diets may result in lowered appetite, weight loss, poor growth, depressed reproductive performance and reduced milk production (Parish 2009).

Ruminants are able to utilise bacteria and protozoa in the rumen to synthesise many of the amino acids that they require as long as they have an adequate supply of rumen-available N and a source of rumen fermentable energy (Carter 2007; Marston 2008). Further down the tract amino acids become available from by-pass protein. However, it may not enough to meet the requirement of high-producing animals (Rush 1997). Requirements depend on the rate of gain and the composition of the growth (Dryden 2008). Therefore, the requirements of both the rumen microorganisms and the animal needed to be considered (NRC 2000).

Protein requirements have little significance if energy requirements have not been met (Preston and Leng, 1987). Protein and energy requirement are interlinked. The energy (correlated with forage digestibility) and nitrogen in diet are sufficient for microbial growth when the ingested forage contains more than 25 g N kg⁻¹ DOM (Egan 1976). Egan and Walker (1975) found that the truly digestible true protein of microbial origin would only support gains of 200 g day⁻¹ in young cattle due to the assumption that this is met with ammonium compounds; for these animals there may be need for the addition of specific amino acids and peptides (Wright and Hungate 1967). Orskov (1990) found that the protein requirement for maintenance and growth of young steers of less than 200 kg live weight, was not met by only microbial protein; therefore Egan and Walker (1975) suggested that in young cattle a source of by-pass protein was required for gains greater than 200 g day⁻¹.

Metabolisable protein is the protein that reaches the small intestines and is made up of microbial protein and bypass protein (protein that escapes rumen degradation)

(Rush 1997; Carter 2007; Dryden 2008; Parish 2009). In the intestine, metabolisable protein is absorbed and used by the animal directly (Carter 2007). The chemical and physical composition of the food, the nature of the microbial population and the rate of passage of undigested food through the rumen are factors that influence the extent to which food is digested by rumen microorganism (Dryden 2008). To estimate the by-pass protein, the NRC (2000) model assumes that amount of microbial protein produced is in relation to the amount of energy in the ration.

Another interaction between energy and protein is that the estimated contribution of protein turnover is dictated by the total energy expenditure (Hunter *et al.* 1993). The link between basal metabolic rate and whole body protein synthesis is reported by Lobley *et al.* (1980) - the cost of protein synthesis is around 12-22% of the direct of total energy expenditure in well-nourished cattle gaining weight rapidly and less than 11% in cattle losing weight (Hunter and Magner 1990).

2.5. Compensatory growth

Compensatory gain is described as a period of faster or more efficient rate of growth following a period of nutritional or environmental stress (CSIRO 2007; FAO 2008). Compensatory gain can be due to increased protein deposition, reduced maintenance and greater feed intake (Ryan *et al.* 1993) or may be due, in part, to a greater net efficiency (k_g) of ME use (CSIRO 2007).

Ryan (1990) reported that increased deposition of protein relative to fat, reduced maintenance requirement and greater feed intake have all been identified as mechanisms contributing to compensatory growth. The response to previous nutritional deprivation is highly variable; at similar body weights, body fat may be decreased or increased after a re-alimentation period. Differences among animal genotypes, severity, nature, and duration of restriction, and nutritional regime and interval of measurement of the response during re-alimentation are among the many variables contributing to differences (NRC 2000).

A reduced maintenance requirement contributes to compensatory growth by increasing the energy available for growth (Ryan *et al.* 1993). It is likely that these two mechanisms, greater protein deposition and reduced maintenance requirement,

are related. When food intake is restricted the metabolically active tissues such as the digestive tract and the liver are likely to be reduced in size and activity. This would reduce maintenance requirement during under nutrition (Ryan *et al.* 1993).

Complete compensatory growth occurs when animals suffer dietary restriction and attain the same weight for age as un-restriction animals (Reid and White 1977). The extent to which the animal is able to compensate will largely depend on the nature of the restriction, the age of the animals, the relative mature weight of the animals, younger animals show a stronger compensatory growth response than older animal and condition of the animals; animals in poor condition when restricted may not able to recover (Reid and White 1977).

2.6. Comparison of energy and protein requirements of cattle breeds in the tropics

In the tropics, both energy and protein are often limiting and seriously reduce animal performance, with protein deficiencies of particular important during lactation and growth of animals (Petty and Cecava 2006). The ability of cattle to perform well in tropical environments varies between breeds. Some researchers have found that animals with the genetic potential for high productivity may be disadvantaged in nutritionally or environmentally restrictive environments (NRC 2000). *Bos indicus* animals are more productive in northern Australia as they have lower maintenance energy requirements and cope better with the periods of nutritional stress (Frisch and Vercoe 1984).

However, *Bos indicus* cattle do not perform as well as their *Bos taurus* counterparts when feed is plentiful and high quality; feed intake per unit live weight and growth rates are lower (Frisch and Vercoe 1984). In a study with a range of genotypes including *Bos indicus*, *Bos taurus* and their crosses, Frisch and Vercoe (1984) found that the ratio of fasting metabolic rate to voluntary feed intake of a high-quality roughage diet was reasonably constant. As a consequence, *Bos indicus* cattle require more time to reach slaughter weight.

In a study comparing Brahman and Hereford cattle O'Kelly and Spiers (1992) found that Brahman, as tropical breeds, achieve and maintain a higher body weight because

higher levels of metabolisable energy and essential nutrients are supplied from the rumen to their body tissue. Evidence shows that a greater population of protozoa was produced by Brahman cattle compared to Hereford cattle when fed lucerne hay and low-quality hay in Africa; Brahman cattle were more able to more rapidly degrade low-quality hay in the rumen and to supply a greater amount of essential fatty acids to body tissues. The Brahman is considered to have fasted for a longer period of time because the residual feed in their rumen is fermented at a more rapid rate. The conclusion of the study was that Brahman cattle have a microbial population which is more suitable for tropical conditions.

ARC (1980) reports that steers grazing native pasture in northern Australia gain on average only 100 kg per year and require more than 5 years to reach slaughter weight; by this time 80% of their lifetime energy intake has been utilised for maintenance requirements. However Minson and McDonald (1987) found that the annual live weight gain of steers was doubling (annual gain was 200 kg in 2-5 years and 150 kg 3-5 years respectively). Maintenance energy requirement therefore was reduced by 50 and 10% and the time requirements for slaughter approximately 5 and 2 months respectively earlier for those steers

Another study by Elliot and Topps (1963) found that African cattle were in positive nitrogen balance when given diets of low protein but high energy content. This may be influenced by a factor of natural selection whereby a physiological process for conserving N under such stress conditions such as in a protein-deficient environment. Recycling of nitrogen is important for ruminants on low protein diets. The low endogenous N loss of the African cattle would be consistent with this hypothesis.

In this respect, Toliehere *et al.* (1990) reported that Bali cattle (*Bos javanicus*) are true tropical animals. They have high heat tolerance even when crossed with *Bos taurus* (Yusran *et al.* 1990). Under poor environment conditions, Bali cattle maintain their productivity by producing calves every year, and quickly recover their body weight after exposure to poor nutritional conditions or heavy work. In this respect, they are a better breed than the Sumba Ongole cattle. Although little information is available on the energy requirements and protein conversion efficiency for Bali cattle

there is some evidence that they may undergo compensatory gain after the dry season.

It is important that cattle which consume lower quality forages have access to sufficient quantity of feed and energy supplementation as appropriate (Parish and Rhinehart 2008). The level of voluntary feed intake decreases with lower digestibility, compounding, rather than compensating for, the effects of inadequate diets. Feed intake in the tropics may also be restricted because of the high water content of the herbage, particularly in the wet season. Improved digestibility means that the greater proportion of the feed is actually absorbed by the animal (FAO 2008).

Therefore, due to weather conditions, the availability of feed, both in quality and quantity is limited resulting in low growth rates of Bali cattle in East Timor. It is necessary to find out, not only the feed resources which are available at any time, but to identify those of high quality. Rice straw is abundant after harvest and of little direct use to the farmer; however it has a low nutrient content, containing high fibre and low protein levels. Chemical approaches such urea-treatment can be used to improve nutrient value. *Leucaena* (*Leucaena leucocephala*) is another feed option which is used by many farmers; it has a high nutrient content and is available throughout the year. This study will provide comprehensive information for farmers on ways to provide diets to meet animal nutrient requirements by utilising feed which is available and of good quality. The results of this study will provide guidelines for cattle farmers in East Timor through the estimation of the metabolisable energy requirements for maintenance, for growth, water requirements and dry matter intake under two feeding systems.

All experimental protocols conformed to the Code of Practice formulated by the National Health and Medical Research Council of Australia and implemented by the Animal Ethics Committee of Curtin University of Technology. The approval number was N17-10 and the approval period was from 25-1-2010 to 31-12-2010.

There were two experiments in this research project. These experiments were conducted at the beef cattle facilities of Co-operativa Cafe Timor (CCT) at Comoro, Dili, East Timor from 25 January to 18 April 2010.

3.1. Animals - type and source

Ten Bali cattle (*Bos javanicus*) bulls were used in these experiments. The bulls were between one and a half and two years of age, and weighed between 100 and 200 kg (mean, 123.70 kg; sd \pm 11.79 kg). There were 12 bulls available and the unselected bulls were kept as reserves. Bulls were collected randomly from farmers around East Timor, and brought to CCT about 2 months before the experiment commenced. During the preparation period the bulls were located in individual pens at CCT and fed harvested leucaena branches and leaves *ad libitum*. Bulls were weighed as they arrived at the CCT areas so as to select animals with an appropriate body weight for the research. In addition to those selected into the experiments, two bulls were kept as reserves; they were fed fresh leucaena.

3.2. Housing

The feedlot facility at Comoro consisted of two rows of adjacent, semi-open stalls separated by an access way (Figure 3.1). The covered stalls were 2 m wide and 2.5 m deep and had concrete troughs and floors. Metal rails between each two stalls provided separation and enabled the bulls to be tethered (in line with common village practice). Each stall was equipped with an individual feeder and water trough. The area between each row of stalls enabled access for feeding and collection of refusals. A one-stall separation between adjacent animals ensured that cattle could not eat the feed nor drink the water given to adjacent animals.



Figure 3.1 **The feedlot facility at Comoro showing the cattle in the semi-open stalls**

3.3. Weighing

The bulls were weighed before the initial allocation to the treatments. Each bull was weighed weekly before feeding using an animal weigh scale (Iconix FX1 digital indicator, Sensortronic Ltd, Hamilton, NZ, 2008).

3.4. Daily routine

Pens were washed every morning after collection of feed refusals. All pens were cleaned with a flowing water spray. Pen floors and water troughs were scrubbed with a brush. Drinking water was changed every 2 days except that during the water intake collection period in Experiment 2 the water was changed every day.

Bulls were fed twice daily, once in the morning at about 0800 h (60% of daily allowance) and again in the afternoon at about 1600 h (40% of daily allowance). A mineral supplement was offered in the morning, mixed into the morning diets.

Refusals were collected every morning before feeding.

3.4.1. Straw and leucaena collection and processing

Rice straw was collected from rice fields throughout East Timor following the harvest of December 2009. The rice straw was stored in empty pens at the CCT farm

and air dried for three days before treating with urea. The rice straw was treated with 4% urea on a dry matter (DM) basis and incubated for 2 weeks.

Leucaena was harvested daily from the small plantation at the CCT facility. Leucaena was treated the same for both experiments.

3.4.2. Preparation of leucaena and rice straw for feeding

Leucaena leaf and small stem were separated from the thick branches (> 0.5 cm thickness); only branches less than 2.5 mm thick were kept to feed. Leucaena was chopped into 5 to 10 cm pieces using a mechanical chopper (figure 3.2) prior to weighing for each animal. Immediately prior to feeding, the urea-treated rice straw was cut, using a cane knife, into pieces about 5 to 10 cm long before weighing daily feed allocation for each animal.



Figure 3.2 Mechanical chopper used to process fresh leucaena daily

3.4.3. Daily preparation

Feed was prepared in the afternoon for the following day. The appropriate amount of feed was weighed for each bull and placed into a separate, labelled nylon bag. The feed was stored in those bags until feeding the following day. The feed bags were kept open to allow free air circulation.

3.4.4. Mineral block supplement

Each bull was given, in the morning feed, 10 g of a complete mineral mix (Prominavite Mineral Block, Prominavite Stocklick Manufacturers, Bullsbrook WA; Table 3.1). The mineral block was shaved with a knife to make a loose mixture and to ensure feeding of the correct amount.

Table 3.1. Analysis of Prominavite Mineral Block
(Prominavite Stocklick Manufacturers, Bullsbrook WA)

Analysis	
Crude Protein	1.5%
Calcium	16%
Phosphorus	0.6%
Sulphur	0.5%
Salt	30%
Molasses	10%
Copper	50mg/kg
Cobalt Chloride	30mg/kg
Potassium Iodine	30mg/kg
Zinc Sulphate	500mg/kg
Selenium	2.5mg/kg

3.5. Sample collection

3.5.1. Feed samples

Feed samples from the adjustment periods of both experiments were not collected. A grab sample (about 50 g) of each of the forages was collected each day during the data collection periods of both experiments and during the digestibility periods. There was one composite sample for each animal for each experimental period.

3.5.2. Refusals

Feed not eaten by each animal was collected once daily before the morning feeding; refusals were weighed for each animal and then mixed thoroughly so that any

remaining leucaena was well mixed within the rice straw. Refusals were not collected in the adjustment period in either experiment.

Refusals included feed that was spilled while the animal was eating, and feed that was spilled into the water trough when the animal drank - the spilled feed was collected from the water trough using a sieve, 2 or 3 times in the hour or two after feeding. The spilled feed was sun-dried and dried in the oven before weighing.

Refusals from the digestibility period in each experiment were brought to Australia for analysis. There was one composite sample for each animal of each experiment from the digestibility trial.

3.6. Prediction of required metabolisable energy intake

3.6.1. Energy requirement

The experiments were designed to provide bulls with a daily metabolisable energy (ME) intake as a multiple of the estimated maintenance ME requirement (ME_m) (MJ/day) based on each animal's initial liveweight. To obtain a preliminary estimate of feed requirement, the expected maintenance energy requirement for each bull was calculated using the CSIRO equation for *Bos indicus* cattle (CSIRO, 2007) as there was no available equation for Bali cattle.

The equation used was:

$$ME_m \text{ (MJ/d)} = k.s.m (0.28W^{0.75} \cdot \exp(-0.03A))/k_m + 0.1ME_p + ME_{\text{graze}} + E_{\text{cold}}$$

(CSIRO, 2007- equation 1.19).

The following assumptions were made for the Dili experiments:

$k = 1.2$ for *B. indicus*

$s = 1.15$ (bulls)

$m = 1$ ($m = 1$ where there was no milk in the diet)

$A = 1.5$ (an age of 1.5 years was used as this was the youngest age of the bulls used in the experiments; the difference between age 1.5 and 2 years is considered insignificant).

k_m = efficiency of utilisation of metabolisable energy for maintenance, calculated as $0.02 \text{ M/D} + 0.5$ (CSIRO, 2007 – equation 1.21)

ME_p = ME used for production (including growth), for the purposes of these calculations it was assumed to be zero.

E_{graze} (energy used in grazing) and E_{cold} (energy required to maintain body temperature) were taken as zero as the animals were confined in pens and in a warm tropical environment.

3.7. Digestibility trial

3.7.1. Feeding

In Experiment I the digestibility trial ran for 7 days in week 5 of the experimental period while in Experiment II there was 8 day collection in the last week of a 6 week experimental period. During the digestibility trials the bulls were fed at the same level as in the introductory feeding period; no adjustment was made for weight gain or weight loss. Feed samples were dried as in the feeding period. There was one composite feed sample for each animal for the total period of each experiment.

3.7.2. Refusals

The refusals during the digestibility period were collected as for the feeding period. A composite sample was made from the dried material and placed in a labelled plastic container for chemical analysis. There was a separate sample for each animal.

3.7.3. Faeces

The total amount of faeces voided was collected separately for each animal twice each day, at about 0800 before the morning feeding and at about 1600 before the afternoon feeding. Faeces were collected from the concrete stall floor by metal scoop. The concrete floor was washed after the faeces were collected, and the floor was swept clear of water with a squeegee.

At each collection, the faeces for each animal were weighed and the weight recorded; the faeces were thoroughly mixed and a 1% (by weight) sub-sample taken. These

sub-samples were placed in air-tight plastic containers, one for each animal, and stored at 5°C. The daily faecal sub-samples were combined over the digestibility period to produce a single composite sample for each animal. The samples were dried in an oven for 24 h at 70°C and placed in air-tight plastic containers. The samples were sent to Perth for chemical analysis. .

3.8. Analytical methods

3.8.1. Sample preparation

All samples that were sent to Perth for analysis were dried in a Couthier Standard oven at 40°C for 15 minutes before grinding. Samples were ground using a cross-beater mill (Retsch, 2006) and through a 1 mm sieve. Samples were stored in labelled plastic containers.

3.8.2. Dry matter

The dry matter (DM) content of each sample (feed, refusal and faeces) was measured by drying (in duplicate) in a laboratory oven at 55°C for 24 hours (AOAC, 1995). The samples were cooled in a desiccator for 30 minutes before weighing. The dry weight was recorded and DM content calculated as percent (%).

3.8.3. Protein analysis

Protein was determined using a semi-macro Kjeldahl method with Se catalyst, by means of a Kjeltec digestion block (model 2006) and Kjeltec 1002 distillation unit (FOSS, 2008).

3.8.4. Acid Detergent Fibre (ADF)

The FibercapTM 2021/2023 apparatus (FOSS, 2003) was used to determine the ADF content of each sample.

3.8.5. Gross energy

An IKA C 2000 Calorimeter was used to calculate the gross energy content of each sample (feed, refusals and faeces) (IKA Version 1, Germany 2000)

3.8.6. Energy digestibility

In vivo energy digestibility was calculated as follows (Dryden 2008):

$$E_{\text{dig}} = \frac{[(F_{\text{food}} \times E_{\text{food}}) - (F_{\text{ref}} \times E_{\text{ref}})] - (F_{\text{aout}} \times E_{\text{faeces}})}{[(F_{\text{food}} \times E_{\text{food}}) - (F_{\text{ref}} \times E_{\text{ref}})] - (F_{\text{ref}} \times E_{\text{ref}})}$$

Where

F_{food} = amount of food offered (g DM/day)

F_{ref} = amount of food refused (g DM/day)

E_{food} = gross energy content of food refused (MJ/kg DM)

F_{aout} = amount of faeces voided (g DM/day)

E_{faeces} = gross energy content of faeces (MJ/kg DM)

The ME content calculated used an estimated ME content by assuming that ME = 0.81 DE and that the 0.81 comes from ARC (1980).

Chapter 4

Experiment1. Energy Requirement for Maintenance and Growth of Bali Cattle in East Timor Fed Urea-treated Rice Straw and Fresh Leucaena

4.1. Introduction

East Timor has a tropical climate with two seasons; the dry season from April to October, and the rainy season from November to March. The average monthly rainfall in the rainy season is 100-150 mm while during the dry season it is less than 10 mm. The daily temperature is more than 30° C throughout the year and highest in August (34° C). During the dry season, the quantity and quality of pasture reduces sharply, limiting the availability of feed. As the dry season progresses forage feed becomes less digestible, due to high levels of fibre and low protein content, and quality also declines due to decreasing contents of essential minerals such as phosphorus.

These changes in feed quantity and quality affect the productivity of Bali cattle in East Timor. Cattle are usually mated and conceive during the rainy season so that calving occurs during the dry season, resulting in poor milk supply and high calf mortality (Toelihere, 2003). A study by Fattah (1998) reported that for cattle on native pasture in Nusa Tenggara about half of the calves born during the dry season died within one year of birth. Moreover, even if they can survive, the growth rate of the surviving calves may be depressed during the dry season, resulting in long-term effects such as delayed puberty (Wirdahayati, 1994). Wirdahayati and Bamualim (1990) found that during the dry season Bali cattle of all ages lose weight excessively.

Soares and Dryden (2003) found that the body condition of Bali bulls in East Timor varies considerably within districts. This indicates that different owners vary in their ability to find feed for their animals, or have different amounts of time to care for them, or that the level of understanding of animal requirements varies between different animal owners. Data from experiments (e.g. Jelantik, 2003) show that Bali

cattle will perform well if fed a high-quality ration. Djajanegara and Rangkuti (2009) recorded live-weight gains of 168 and 254 g/day when cattle were fed rations containing elephant grass and sugar cane. Average daily gains of Bali cattle fed grass pasture with no additional feed supplement were 176 g/day, but increased to 314 g/day when provided with concentrate feed supplement at a rate of 1.8% of body weight per day (Fattah, 1998). Moran (1978) found that Bali cattle given high quality feed had average daily gains of 660 g/day and Bamualim and Wirdahayati (2003) found that offering a diet of 50-60% grasses and 40-50% mixed legumes and field grasses instead of feeding mostly leucaena increased daily weight gain from 0.2 kg/head/day to 0.5 – 0.8 kg/head/day.

It is clear from the above discussion that there is room for substantial improvement in the productivity of Bali cattle in East Timor and that much of this will come from improved feeding management. Approximately 60% of East Timor's beef cattle are hand fed with pasture grass, legume forage and by-products from cropping (Salsinha *et al.* 2008), so there is potential to improve productivity with improved feed rations. However, successful hand feeding requires information on the nutrient requirements of the cattle and on the nutritive values of the feeds available. Apart from reports of responses to different feeding systems similar to those described above, there is no published information on the nutrient requirements of Bali cattle. Similarly, there is very limited published information on the nutritive value of East Timorese feedstuffs.

The purpose of this study was to determine the energy requirements for maintenance and growth of Bali cattle in East Timor.

4.2. Hypothesis

Energy requirements for maintenance and growth of Bali cattle (*Bos javanicus*) are not different to that predicted for *Bos indicus* cattle.

4.3. Materials and methods

4.3.1. Design

Experiment 1 was conducted over 35 days from 25 January to 28 February 2010. The experiment comprised a one-week adaptation period followed by a four-week experimental period that included a one-week digestibility collection period in the final week.

4.3.2. Treatments

Six levels of metabolisable energy (Table 4.1), calculated as multiples of the estimated metabolisable energy requirement for maintenance (ME_m), were used to obtain a range of animal growth responses. In order to design treatments which would give the required range of ME intakes, the expected ME_m (MJ/d) were calculated from equation 1.19 of CSIRO (2007), using the coefficients recommended for *Bos indicus* cattle.

The expected ME contents of the two forages used to make the diets were estimated from the relationship:

ME content (MJ/kg DM) = DM digestibility \times expected gross energy content of plant DM (MJ/kg DM) \times 0.81.

Dry matter digestibilities (DMD) from Chuzaeni and Soejono (1987) were used, the estimated gross energy (GE) content of plant dry matter was assumed to be 18.4 MJ/kg DM (MAFF 1975, CSIRO 2007), and the factor of 0.81 used to convert DE to ME was obtained from CSIRO (2007). The expected efficiency of use of ME for maintenance (k_m) was calculated from the published DMD data using equation 1.21 of CSIRO (2007). The amount of feed provided to each animal was calculated on an individual basis, according to the initial live weight of each animal.

4.3.3. Feed Preparation

The diets were a mixture of 56% (DM basis) urea-treated rice straw and 44% fresh leucaena forage (consisting of the petioles and small branches). The ration was

formulated to provide the expected protein requirement (14%, DM basis) of these cattle.

The rice straw was obtained from the Bacau region of East Timor. The straw remaining after the ripened seed head with grain had been removed was harvested from the field, transported to the research site, and air-dried for three days. After drying, the straw was treated with 4% urea on a dry weight basis. Urea was mixed with water to obtain a solution which was spread on the straw and mixed completely through the straw manually. The treated rice straw was covered with a tarpaulin and incubated for two weeks. Following incubation, the urea-treated rice straw was air-dried for at least two days before use. Immediately prior to feeding, the straw was cut, using a cane knife, into pieces about 5 to 10 cm long before weighing the daily feed allocation for each animal.

Leucaena forage was harvested daily from a plantation at Comoro, East Timor, and was processed as described in Chapter 3 (see 3.2.3.1.).

To reduce errors in feeding, the two ingredients were weighed separately and mixed together in the feed troughs. Initial estimates of the chemical composition and digestibility of these two ingredients are given in Table 4.1. These initial estimates were used to construct the diets used in this experiment.

Table 4.1. Dry matter and estimated digestibility energy contents and efficiency of utilisation of ME (k_m) of the feeds used in Experiment 1; this data was used to construct the treatments used in this experiment

Constituent	Urea-treated rice straw	Leucaena
DM (%) ¹	91.10	36.10
DMD (%) ²	50	65
GE (MJ/kg DM) ³	18.40	18.40
ME (calculated) (MJ/kg DM)	7.45	9.69
k_m	0.65	0.69

¹Measured prior to day one of the experiment; ²Chuzaeni and Soejono (1987);

³CSIRO (2007).

4.3.4. Animals

Ten Bali cattle (*Bos javanicus*) bulls were used in this experiment. They were between 1.5 and approximately 2 years old, with an average initial weight of 123.7 kg (sd = 11.79; range = 109 to 142 kg). The treatments were allocated at random to animals, with either one or two bulls allocated to each treatment, as shown in Table 4.2.

Details of the pens used, and of the allocation of animals to pens, are given in Chapter 3.

Table 4.2. Treatment allocation, initial live weight, and estimated ME requirements for maintenance of the animals used in Experiment 1.

Treatment (\times ME _m)	Bull no.	Initial BW (kg)	ME _m (MJ/day) ¹
0.75 (A)	7	129	21.34
0.75 (A)	9	132.5	21.77
1.00 (B)	6	142	22.93
1.00 (B)	10	116	19.71
1.25 (C)	2	109	18.81
1.50 (D)	4	111	19.06
1.50 (D)	8	140	22.69
1.75 (E)	1	114	19.45
1.75 (E)	5	123.5	20.65
2.00 (F)	3	120	20.21

¹expected values, calculated from CSIRO (2007)

4.3.5. Measurements

Feed intakes and digestibility were measured by total collection, as described in Chapter 3. The bulls were fed twice daily; at 0800 and 1500 h. Refusals were collected before the morning feeding. Dry matter (DM) intake was calculated as the

difference between the DM offered and that refused. Faeces were collected twice daily, just prior to the morning feeding and at 1700 h, from the concrete floor of the pen.

Live weights were measured using an electronic cattle scale (Iconix FX1 digital indicator, Sensortronic Ltd, Hamilton, NZ) at weekly intervals. The cattle were weighed before the morning feeding. Rates of live weight change were calculated by linear regression of live weight on time (elapsed days).

4.3.6. Sample processing and analysis

The dry matter (DM) contents of the feed ingredients offered, and of the refusals were measured daily, by drying at 55 °C until weight was achieved. Faeces subsamples were collected daily and composited over the collection period (stored at 5 °C), then dried at 55 °C until constant weight. These dried samples were then ground (1 mm screen) and analysed for ADF, N and energy analysed as described in Chapter 3.

4.3.7. Statistical analysis

Linear regression analysis was used to investigate relationships between feeding level (treatment) and growth and digestibility responses.

4.4.Results

4.4.1. Nutrient composition of the feeds

The nutrient composition determined for the feeds used in Experiment 1 are shown in Table 4.3.

Table 4.3. Composition (mean \pm sd) of the ration ingredients and the final ration

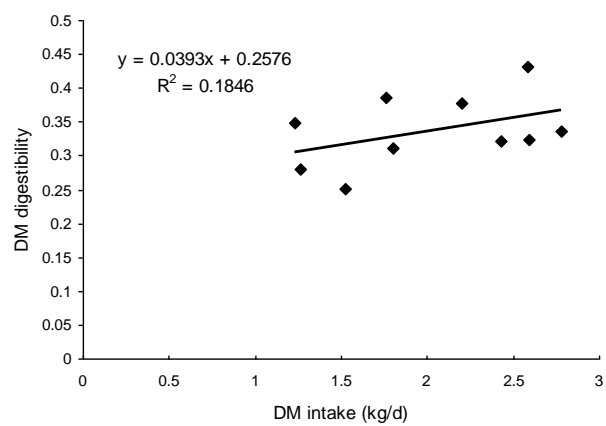
Parameter	Urea treated- rice straw	Leucaena	Whole ration
Ingredient proportion (DM basis)	0.52 \pm 0.0004	0.48 \pm 0.0004	
Nutrient content			
DM (%)	73.1 \pm 13.58	30.3 \pm 7.79	52.8
Crude Protein (% DM)	6.6	15.5	10.8
ADF (% DM)	63.6	42.7	53.7
Gross energy (MJ/kg DM)	16.7	19.9	18.2

4.4.2. Digestibility and available energy content

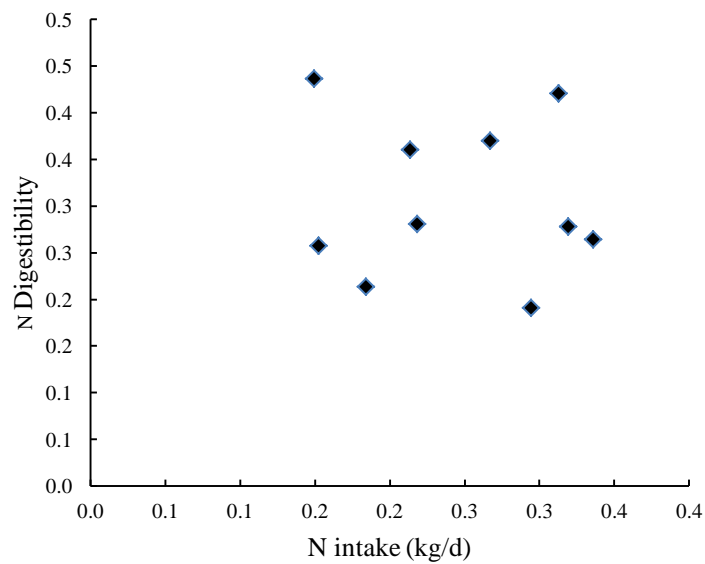
The digestibility of all ration constituents was very low. The mean apparent DM digestibility was 33.7 \pm 8.5 (mean \pm sd), and ranged from 25 to 43% (Table 4.4). The mean apparent digestibility of N was 22.1 \pm 0.94, and ranged from 19 to 43%. Mean ADF digestibility was 30.7 \pm 6.2, ranging from 14 to 33%, and was similarly low. Mean energy digestibility was low (37.5 \pm 5.1), and ranged from 28.5 to 47.1%. Although there appeared to be positive relationships between constituent intake and digestibility for all feed constituents except N (Fig. 4.1), these were non-significant. P values were: DM: P = 0.215, ADF: P = 0.144; and Energy, P = 0.286.

Table 4.4. Apparent % digestibility of dry matter (DM), crude protein (CP), acid detergent fibre (ADF) and energy (GE, DE, ME) (MJ/kg DM), and concentrations of available nutrients determined in the ration used in Experiment 1

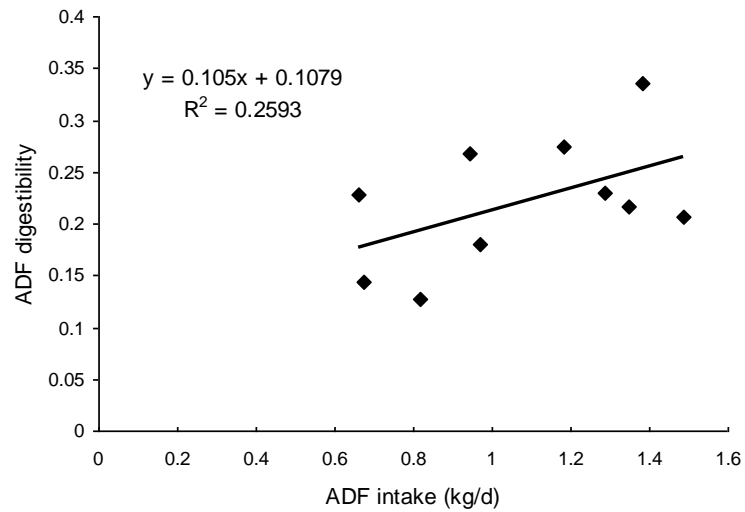
Treatment	A	A	B	B	C	D	D	E	E	F
Bull no.	7	9	6	10	2	4	8	1	5	3
Constituent digestibility (%):										
DM	34.9	27.9	38.5	25.1	31.2	37.8	43.2	32.1	33.6	32.4
CP	43.7	25.7	36.0	21.4	28.0	37.0	42.0	19.1	26.4	27.8
ADF	22.7	14.5	26.7	12.7	18.0	27.5	33.5	22.9	20.7	21.6
GE	39.3	33.1	41.9	28.5	35.3	40.5	47.1	36.2	37.3	35.3
Available nutrient content (% DM basis):										
Digestible DM	33.8	32.1	34.7	31.4	32.9	34.5	35.8	33.1	33.5	33.2
Digestible CP	4.9	2.9	4.1	2.4	3.2	4.2	4.8	2.2	3.0	3.1
Digestible ADF	10.2	5.8	12.2	4.8	7.6	12.7	15.8	10.1	9.1	9.2
Available energy content (MJ/kg DM):										
DE	7.2	6.0	7.7	5.2	6.4	7.4	8.6	6.6	6.8	6.5
ME	5.8	4.9	6.2	4.2	5.2	6.0	7.0	5.4	5.5	5.3



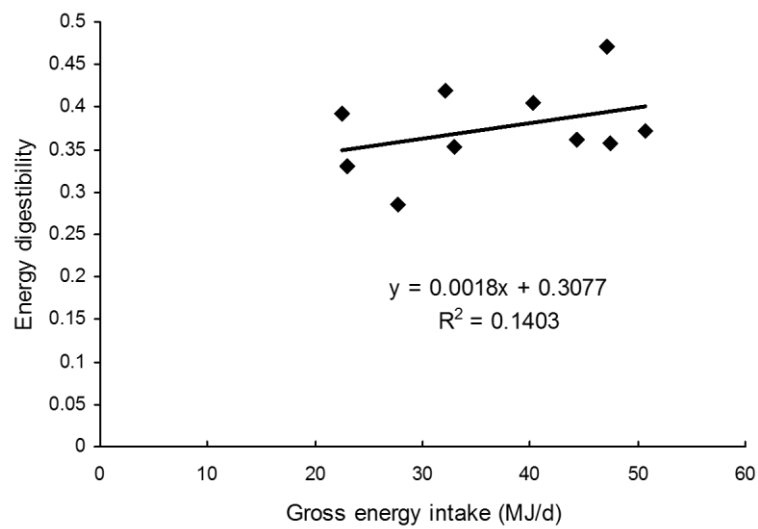
(a) DM digestibility



(b) N digestibility



(c) Acid detergent fibre digestibility



(d) Energy digestibility

Fig. 4.1. Relationships between constituent intake and digestibility for Bali cattle fed a ration of urea-treated rice straw and leucaena

4.4.3. Feed and nutrient intake

Dry matter intake, averaged over the whole experiment, ranged from 1535 to 3769 g per day. Table 4.5 shows DM intake for individual bulls; means \pm sd are given. These are calculated from the daily intakes recorded for each animal throughout the whole experiment, and during the digestibility period.

Table 4.5. Daily dry matter and nutrient intake (standard deviation in brackets)

Treatment	A	A	B	B	C	D	D	E	E	F
Bull no.	7	9	6	10	2	4	8	1	5	3
Daily DM intake, whole experiment: ¹										
g	1535 (262.4)	1578 (261.4)	2221 (371.2)	1912 (317.6)	2269 (380.6)	2732 (466.2)	3280 (559.7)	3238 (617.8)	3484 (576.6)	3769 (892.0)
g/kg W ^{0.75}	50	41	59	58	64	80	80	90	88	99
% W	0.2	0.1	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3
Daily DM intake, digestibility period: ²										
g	1232 (42.3)	1260 (38.1)	1762 (37.9)	1522 (48.2)	1805 (52.1)	2205 (64.2)	2582 (82.3)	2427 (171.6)	27789 (87.6)	2592 (670.2)
g/kg W ^{0.75}	42	34	48	47	52	64	63	67	70	68
% W	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Daily nutrients intake , digestibility period ²										
CP (g/d)	21	22	31	26	31	38	45	42	38	46
ADF(g/d)	661	676	945	816	968	1182	1381	1285	1489	1346
DE(MJ/d)	1.03	0.86	1.09	0.74	0.92	1.06	1.23	0.94	0.97	0.93
ME(MJ/d)	0.83	0.70	0.89	0.60	0.74	0.86	1.00	0.77	0.79	0.76

¹ liveweights are the means of those recorded during the whole experiment

² liveweights are the means of those recorded on Days 28 and 35.

4.4.4. Liveweight change

Table 4.6 shows live weight changes during Experiment 1.

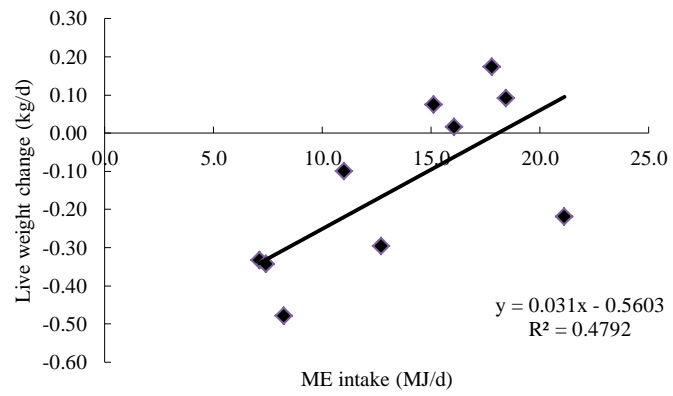
Table 4.6. Liveweight, and rates of live weight change, of Bali bulls fed different amounts of energy

Treatment	Elapsed days	A	A	B	B	C	D	D	E	E	F
Bull no.		7	9	6	10	2	4	8	1	5	3
Adaptation		109	142	132.5	116	123.5	111	140	114	129	120
Treatment	5	103.5	131.5	128	110.5	114.5	109.5	146	117	130.5	125
	7	104	131.5	129.5	109.5	116	110	146.5	120	133	126.5
	14	99.5	131.5	126	107.5	117	113	140	120	134	126.5
	17	97	128.5	126.5	104.5	118	112	144	121.5	136.5	130.5
	21	97	128.5	127.5	102	116.5	112.5	144	118.5	138.5	129.5
	22	95	126.5	125	100.5	114.5	110.5	139	117.5	137	125.5
	28	93.5	123.5	121.5	103.5	113.5	111.5	140.5	120	133.5	129.5
	34	90	123	120	101	112.5	112.5	140	119	137	127.5
LWG (kg/d) ¹		-0.48	-0.33	-0.30	-0.34	-0.10	0.07	-0.22	0.01	0.17	0.09

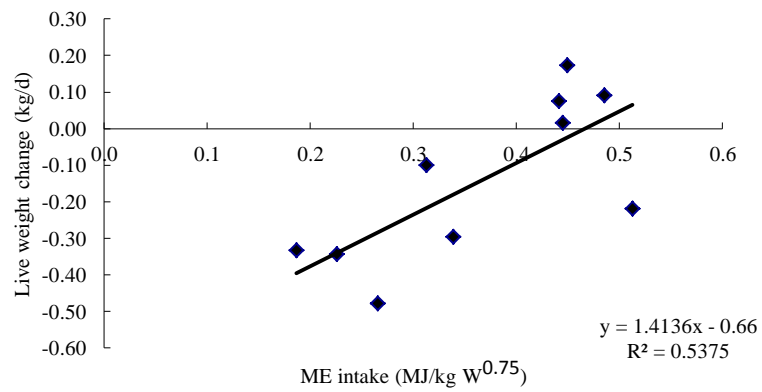
¹Live weight change measured from week 1 to 5 included one week of digestibility period at the end of the Experiment.

4.4.5. Metabolisable energy requirements for maintenance and growth

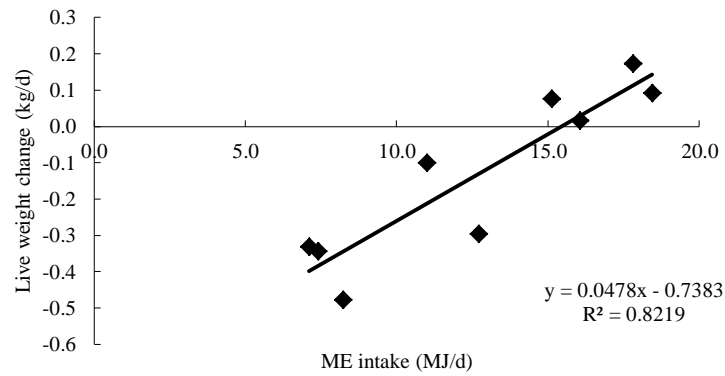
The relationships between live weight change and ME intake are described in Figures 4.2 and 4.3. The fit between live weight change and ME intake was modest ($R^2 \approx 0.5$) when the responses of all bulls were considered. One animal (bull no. 8) was considered to be an outlier as it was given an estimated $1.75 \times \text{ME}_m$ but lost live weight, while the two other bulls given similar levels of ME intake increased in live weight.



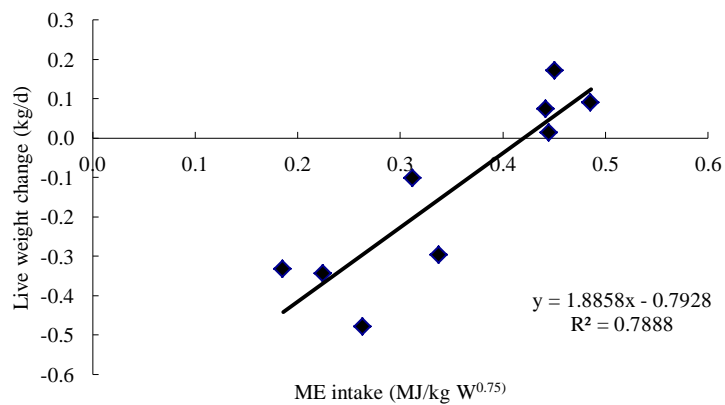
(a) Relationship between total daily ME intake and live weight change



(b) Relationship between daily ME intake scaled to metabolic live weight and live weight change



(c) Relationship between total daily ME intake and live weight change – bull no. 8 omitted



(d) Relationship between daily ME intake scaled to metabolic live weight and live weight change – bull no. 8 omitted

Fig. 4.2. Relationships between ME intake and live weight change of Bali bulls fed a mixed rice straw and leucaena diet.

The regression equations (parameters \pm se) of live weight change (LWC, kg/d) on ME intake (ME, MJ/d; or MJ/kgW^{0.75} per d) and their associated statistics are:

- (i) Live weight change v. total daily ME intake (all data):

$$\text{LWC} = -0.56 (\pm 0.1964) + 0.03 (\pm 0.01341) \text{ ME};$$

$$(R^2 = 0.4792; P < 0.03)$$

- (ii) Live weight change v. ME scaled to metabolic size (all data):

$$\text{LWC} = -0.66 (\pm 0.1773) + 1.41 (\pm 0.4636) \text{ MJ/kgW}^{0.75};$$

$$(R^2 = 0.5375; P < 0.02)$$

- (iii) Live weight change v. total daily ME intake (bull no. 8 omitted):

$$\text{LWC} = -0.74 (0.11786) + 0.05 (0.4747) \text{ ME};$$

$$(R^2 = 0.8219; P < 0.03)$$

- (ii) Live weight change v. ME scaled to metabolic size (no. 8 omitted):

$$\text{LWC} = -0.79 (0.11346) + 1.89 (0.368851) \text{ MJ/kgW}^{0.75};$$

$$(R^2 = 0.7888; P < 0.0014)$$

These regression equations give the following estimates of the ME requirement for maintenance of male Bali cattle:

- (i) With all data considered:

$$\text{ME}_m = 18.09 \text{ MJ/d}$$

$$\text{ME}_m = 0.467 \text{ MJ/kgW}^{0.75} \text{ per day, and}$$

- (ii) With data from bull no. 8 removed:

$$\text{ME}_m = 15.45 \text{ MJ/d}$$

$$\text{ME}_m = 0.420 \text{ MJ/kgW}^{0.75} \text{ per day.}$$

ME requirements for “production” (i.e. positive live weight change of male Bali cattle under the specific conditions of this experiment) are:

(i) With all data considered:

$ME_g = 32.26$ MJ/kg live weight gain, and

(ii) With data from bull no. 8 removed:

$ME_g = 20.92$ MJ/kg live weight gain.

4.5. Discussion

The main aim of this study was to measure the maintenance energy requirement of Bali cattle; subsidiary aims were to estimate the ME requirement for “production” (i.e. live weight gain under the specific conditions of this experiment), and to investigate the applicability to Bali cattle of the CSIRO (2007) maintenance energy prediction equation for male *Bos indicus* cattle.

4.5.1. Energy requirements of male Bali cattle

In this experiment, the energy requirement for maintenance ($MJ/kgW^{0.75}$ per day) was best predicted from the equation:

$$LWC = -0.79 (\pm 0.135188) + 1.89 (\pm 0.3705365) MJ/kgW^{0.75}$$
$$(R^2 = 0.79; P < 0.002)$$

where: LWC = live weight change (kg/d)

This equation omits the data for bull no. 8 which was given an estimated $1.75 \times ME_m$ but which lost live weight, while the two other bulls given similar levels of ME intake increased in live weight. The omission of this bull’s data can be justified because the animal was very temperamental during the experiment.

NRC (2000) stated there are three methods that can be used to measure the maintenance energy requirement: long-term feeding trials to determine the quantity

required to maintain body weight, calorimetric methods, and comparative slaughter. The limited facilities available in East Timor at the time this research was undertaken, meant that the second and third methods could not be easily applied, therefore the regression method was chosen.

The regression method requires the ME content of the feed to be measured. The metabolisable energy value of feed is determined in a feeding trial, in which urine and methane as well as faeces are collected. For an estimation of methane production, respiration chambers are required (Abelhammid and Gabr, 1990). Another calculation of ME which could apply for mixed feeds also that uses the gas production test and contents of crude protein and crude fat, fibre and ash (Menke and Steingass, 1987). Minson (1982) reported that ME could be calculated from digestible energy - this method was used in this experiment.

The ME requirement for maintenance was estimated using a combination of chemical analysis data and prediction equations; in this experiment the ME requirement for maintenance was calculated to be $0.42 \text{ MJ kg}^{0.75}$ per day. CSIRO (2007) and NRC (2000) ME_m adopts $0.448 \text{ MJ/kg W}^{0.75}$ per day to describe the ME_m requirement of young, entire male *Bos indicus* cattle. Due to this limited study on the energy requirement of Bali cattle, the result might be compared to the requirements of other species of cattle. Castro-Bulle *et al.* (2007) discussed the growth, carcass quality, protein and energy metabolism in beef cattle with different growth potentials and residual feed intakes; he found that the ME requirement for maintenance of beef steers (Angus \times Hereford) with high growth potential (HG) or low growth potential (LG) were the same - $0.48 \text{ MJ kg}^{0.75}$ per day. Vermorel *et al.* (1991). A study on the metabolisable energy requirement for maintenance in for adult, non-pregnant, non-lactating Charolais cows (*Bos taurus*), found that the requirement for the LG group was $0.39 \text{ MJ kg}^{0.75}$ and the HG group was $0.58 \text{ MJ kg}^{0.75}$. Tedeschi *et al.* (2002) discussed the energy requirement for maintenance and growth of Nellore bulls and steers fed high-forage diets; this study revealed that *Bos indicus* breeds have lower energy requirements for maintenance than *Bos taurus* breeds. Bali cattle (*Bos javanicus*) are a different species to either British, European or Brahman-type cattle. It could be expected that these animals may have a different ME_m to *Bos taurus*, and possibly *Bos indicus*, animals. The ME requirement for maintenance of Bali cattle

was similar to the outcomes of these studies - 15.45 MJ/d or 0.420 MJ/kg $W^{0.75}$ per day.

Energy for production can be defined as the energy that an animal needs for growth, producing edible products, and/or for exercise or work (Marston, 2008). Energy for production or performance is only available to the animal after the energy demands for maintenance are met. Since most animals in this experiment lost weight, it was not possible to estimate the ME requirement for production. In a weight loss situation, most of the animals would be utilising body tissue as an energy source for maintenance, and the ME required to prevent live weight loss was 20.92 MJ/kg of liveweight potentially lost.

Three factors should be considered when considering these conclusions:

1. animal ages: the metabolic rate tends to slow down as the animals ages;
2. different efficiencies of utilization of ME for maintenance (k_m): these depend on food type, especially for ruminants. Energy from food with lower ME content (MJ/kg DM) is used less efficiently (Dryden 2008). Sainz *et al.* (2007) reported that the k_m for beef cattle with different growth potential was of 0.62, and used CSIRO equation (2007) revealed k_m of this experiment was 0.61

4.5.2. Ration nutritive value

The nutritive value of the ration used in Experiment 1 was lower than expected. The ration composition (53% urea-treated rice straw + 47% leucaena) was similar to that intended, but the protein content of Leucaena was lower than the reference data used to formulate the ration (16 % compared to 24% reported by Chuzaeni and Soejono (1987). In future work, as it appears that published nutritive value data may not apply to East Timorese feeds, it would be advised to test the ingredients before formulating experiment diets.

The gross energy content of the mixed ration used in this experiment was similar to the gross energy content of forage feeds adopted by MAFF (2006), i.e. 18.22 v. 18.4 MJ/kg DM. The calculated ME content of the ration used in this experiment was 5.54 MJ/kg DM, and was lower than the expected value of 8.4 MJ/kg DM. Initial

estimates of ingredient M/D content were calculated from the digestibility data reported by Chuzaeni and Soejono (1987) for similar feeds. CSIRO (2007) reported that M/D of tropical browse legumes was 8+ MJ/kg DM or more.

Metabolisable energy (M/D) of feed is affected by variations in chemical composition (especially ADF and lignin contents), feed preparation (e.g. grinding), and level of feeding, associative digestibility effects of ration ingredients and animal physiological state (CSIRO 2007). The M/D of a mixed diet is the weighted average of the ME provided by each component of the diet. Therefore, if a single ingredient is deficient in nutrients the diet ME content, and its other qualities, will be less than expected because the contribution made by the other components, in themselves nutritionally adequate, have been diluted by the poorer component. The rice straw used in this experiment was collected from Baucau region two to three weeks after the harvest had finished. Rice straw was collected after the rice grain harvest and was cut about 2 or 3 cm above its roots; therefore grain did not add any energy to this urea-treated rice straw. Plants are not homogenous but complex arrangements of roots, stem leaves and inflorescence. Chemical and physical differences between tissues may lead to differences in digestibility (Jayasuria 1986). Hacker and Minson (1981) reported that leaves from grasses may vary in digestibility from 15% to 84%, with a mean 59%, while the digestibility of the stem fraction may range from 5% to 85% (Minson 1982). Jayasuriya (1986) recorded that rice straw has a crude protein content of 3% to 5.1% with a mean 4.1% while ADF was 43% to 57% with a mean 49%. In this experiment, the crude protein content was 7% (after urea treatment) while ADF was 64% (DM basis).

The quality of rice straw is determined by weather conditions, fertiliser application, harvesting time, and the variety (Sundstøl *et al.* 1998). The morphological characteristics, controlled by the genetic makeup, are major factors contributing to the variation of rice straw DM digestibility (Khush *et al.* 1987; Mahendra 1994). Biodegradability of rice straw is affected by biogenic Si content through reduction in cell wall digestibility (Van Soest and Jones 1968; Jackson 1977; Van Soest 1981). Vadiveloo and Phang (1966) reported that the weather, climate, and plant age related to the cultivation season are also important factors affecting the composition and quality of straw.

There is limited information about the varieties of rice used in this area; thus it is not possible to compare the digestibility of the straw used in this experiment with other published data. However, the fact that the straw had lain in the field for some time after cutting suggests that soluble nutrients may have been leached by dew or rain.

Treatment of rice straw is another factor to consider in this experiment. Man and Wiktorsson (2001) found that the application of urea solution application affected nutritive value of treated rice straw. Man and Wiktorsson (2001) revealed that the urease activity of rice straw is low and without any added enzyme it generally take about 2 to 3 weeks for urea to breakdown to ammonia; by adding sources of urease enzyme such soya bean seeds (*Glycine mas.*) L, watermelon seeds (*Colocynthus citrullus* (L) Kunze), pumpkin seeds (*Cucubita maxiuma Duchesme*), jack bean seed (*Canavalia ensiformis*) the time for the effect was reduced from 14 to only 1 or 2 days. In this experiment treated straw was incubated for 2 weeks but the digestibility remained low.

Vadiveloo and Fadel (2009) reported that *in vitro* digestibility of rice straw is affected by varieties of the rice; digestibility (*in vitro*) of 16 varieties of rice straw ranged from 37 to 85%. Sannasgala and Jayasuriya (1986) found a seasonal influence on the digestibility of rice straw fractions, but whole rice straw was not affected by season. The rice straw used in this experiment was stem. However, Bainton *et al.* (1991) showed the effect of season and nitrogen application varied with straw variety. In different seasons and locations *in vitro* rice straw digestibility was reported by Phang and Vadiveloo (1995) to range between 25 and 43% while between two seasons and locations the range was similar (28 – 34%). The digestibility of some plant species is 60% or more (ME = 8 MJ/kg DM). These include various tropical browse legumes (Bamualim *et al.* 1980).

Digestibility is affected by the botanical composition and stage of maturity of the forage and also by the processing and chemical treatment (Miller 1961). A high digestibility means that the greater proportion of the feed is actually absorbed by the animal (FAO 2008). Lower digestibility of tropical species is reflected in the different lengths of time required to digest tropical feeds (Milford 1967); the level of voluntary feed intake decreases with decreased digestibility, compounding, rather than compensating for, the affects of an inadequate diet. In general it is rarely possible to achieve a digestibility level of over 70%. In practical terms, adult

ruminants (except dairy cows and goats) are unlikely to consume a dry matter equivalent of more than 3% of their body weight daily in fed mature forage of only 40% digestibility. In this experiment was found that digestibility lower than from those references.

4.6. Recommendations

Feed available for cattle in East Timor varies widely in nutrient content which influences the ME content. Different k_m and k_g values it is necessary to measure ME_m and ME_g for specific feeds.

It is suggested that research needs to be directed to the determination of energy feeding standards for Bali cattle based on k_m , effect of age, sex and level of production.

It is necessary to measure ME_m under different conditions in East Timor such as season, altitude, and quality of feed. By having this information, agricultural advisors can produce a calendar of feeding strategies for beef production for cattle in East Timor, based on the feeds available, animal age and sex, and climate.

Chapter 5

Experiment 2 - Energy requirement for maintenance and growth of Bali cattle in East Timor fed fresh *Leucaena* diets

5.1. Introduction

In East Timor, most farmers use crop residues and by-products such rice straw or maize straw, and the leaves of fodder trees as feed supplements. Large improvements in ruminant productivity can be expected by offering feeds, other than pasture, which not only have high available nutrient contents but are also available during the dry season. *Leucaena* is known to be a highly productive tropical fodder tree species and is widely used by East Timorese farmers.

Supply of water for animals in East Timor can present a problem during the dry season when its availability is very limited. Most intensively managed animals (e.g. those tethered or kept in pens) are watered by bringing water by hand, often from some distance away. Thus provision of water competes with other demands on farmers' time and labour. Water should always be provided in ample amounts, clean and uncontaminated; if water is limited, feed intake will be depressed, resulting in lower performance (Marston, 2005).

This experiment was designed to investigate further the ME requirements for maintenance and production of Bali cattle in East Timor and to determine water intake of Bali cattle fed *leucaena*. The technique used to investigate these requirements in Experiment 1 gave results which are specific for Bali bulls fed a urea-treated rice straw/*leucaena* forage diet. The same approach was used in this second experiment to obtain similar data for animals fed a diet of *leucaena* forage alone. This information will contribute to improving cattle productivity in East Timor and will provide information to estimate the feed resources needed to increase the performance of Bali cattle in East Timor.

5.2. Hypothesis

This experiment tested the null hypothesis that the metabolisable energy (ME) requirements for maintenance and growth of Bali cattle (*Bos javanicus*) and water requirement of cattle fed a diet of leucaena forage are not different to those predicted for *Bos indicus* cattle.

5.3. Material and methods

5.3.1. Design

The experiment was conducted over 49 days from 1 March to 19 April 2010. It comprised a two-week changeover from a diet of mixed urea-treated rice straw/fresh leucaena to one of fresh leucaena only, followed by a five-week feeding period. The final week of the experiment incorporated a digestibility collection and measurement of the water consumption of the bulls.

5.3.2. Treatments

The experiment had five levels of feeding (Table 5.1); these were intended to provide approximately 0.85, 1.0, 1.4, 1.8 and 2.2 times the ME requirement for maintenance (ME_m), based on the feeding standards of CSIRO (2007) for *Bos indicus* cattle.

5.3.3. Animals

Ten Bali cattle (*Bos javanicus*) bulls were used in this experiment. They were between 1.5 and approximately 2 years old, with an average initial weight of 127.5 kg (sd = 15.24; range = 106.5 to 153.5 kg). The animals were allocated to treatments randomly, with two bulls allocated to each treatment, as shown in Table 5.1. Details of the pens used, and of the allocation of animals to pens, are given in Chapter 3.

Table 5.1. Treatment allocation, initial live weight, and estimated ME requirements for maintenance of the animals used in Experiment 2.

Treatment (\pm ME _m) intended	Bull number	Initial BW (kg)	Expected ME Requirement (MJ/day)
0.85 (A)	9	107.5	16.00
0.85 (A)	10	117	17.05
1 (B)	2	130	21.71
1 (B)	3	135.5	22.40
1.4 (C)	1	124.5	29.42
1.4(C)	5	146.5	33.24
1.8 (D)	6	128	38.63
1.8 (D)	8	153.5	44.27
2.2 (E)	4	122.5	45.68
2.2 (E)	7	106.5	41.13

¹expected values, calculated from CSIRO (2007)

5.3.4. Feeding

The diet was solely leucaena forage (leaflets, petioles, and short sections of small stems < 2.5 mm diameter) which was harvested daily from a plantation at Comoro, East Timor, and processed as described in Chapter 3 (see 3.2.3.1). The measured DM content and estimated energy content and digestibility of the leucaena used in this experiment are given in Table 5.2. These values were used only to construct the treatments.

Table 5.2. Dry matter, and estimated digestibility and energy contents and efficiency of utilisation of ME (k_m), of the leucaena forage used in Experiment 2; this data was used to construct the treatments used in this experiment

Constituent	Leucaena
DM (%) ¹	40
DMD (%) ²	55
GE (MJ/kg DM) ³	18.4
ME (MJ/kg DM) (calculated) ⁴	8.2
k_m	0.66

¹Measured prior to day one of the experiment 2; ²Chuzaeni and Soejono (1987) modified in the light of Experiment 1 results; ³CSIRO (2007); ⁴ = DM digestibility (%) / 100 × GE content (MJ/kg DM) × 0.81

Each days ration was divided into two parts and the cattle were fed twice daily (60% in the morning and 40% in the afternoon) as described in Experiment 1.

Feed on offer was changed over from urea-treated rice straw/fresh leucaena to fresh leucaena only over a period of seven days (Table 5.3). This was followed by a seven-day adaptation period. No intake data were recorded in these periods.

Table 5.3. Details of the changeover from a mixed urea-treated rice straw/leucaena diet to leucaena only during the 7-day changeover period

Day	Leucaena portion (%)	Urea-treated rice straw portion (%)
1-2	50	50
3-4	56	44
5-6	80	20
7+	100	0

5.3.5. Water

Water was available *ad libitum* through the whole experiment, provided in individual troughs. The water was obtained from a bore situated near the bank of the Comoro River, at Comoro.

5.3.6. Measurements

Feed intakes and digestibility were measured by total collection. Refusals were collected each day of the experiment before the morning feeding. DM intake was calculated as the difference between the DM offered and that refused. Faeces were collected during the last week of the experiment, twice daily, just prior to the morning feeding and at 1700 h. Faeces were collected from the concrete floor of the pen.

Live weights were measured using an electronic cattle scale (Iconix FX1 digital indicator Sentsortronic Ltd, Hamilton, NZ) at weekly intervals. The cattle were weighed before the morning feeding.

Water intake was from measured over seven consecutive days. Consumption was calculated as the difference between the volume of water present immediately after filling the trough after the morning feeding (using depths measured at nine points in the trough), and the volume measured before the subsequent morning feeding. Evaporation losses were tested and were found to be small and were thus ignored.

Ambient temperature, humidity and rainfall were measured at the research site using a Maxkon Wireless Digital Weather Forecast Station Thermometer (WS-1050).

5.3.7. Sample processing and analysis

The dry matter (DM) contents of the feed ingredients offered, and of the refusals, were measured daily, by drying at 55 °C until constant weight was achieved. Subsamples of faeces were collected daily and composited separately for each bull

over the collection period (stored at 5 °C). These were then dried at 55 °C until constant weight, ground (1 mm screen) and subsequently analysed for ADF, N and energy as described in Chapter 3.

5.3.8. Statistical analysis

Rates of live weight change were calculated by linear regression of live weight on time (days). Linear regression analysis was used to investigate relationships between feeding level (treatment), and growth (calculated from the whole experimental period) and digestibility responses.

5.4. Results

5.4.1. Nutrient composition of the leucaena

Table 5.4 contains the analytical information for the leucaena that was fed in this experiment.

Table 5.4. Composition (mean \pm sd) of leucaena forage fed to male Bali cattle in Experiment 2

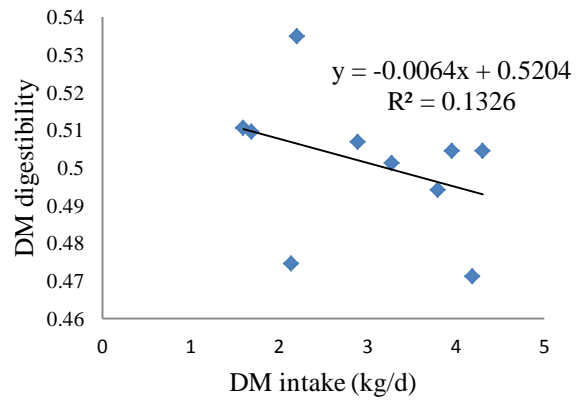
Nutrient	Leucaena
DM (%)	33.5 (\pm 6.25)
Protein (% DM)	20.5
ADF (% DM)	36.9
Energy (MJ/kg DM)	20.1

5.4.2. Digestibility and available energy content

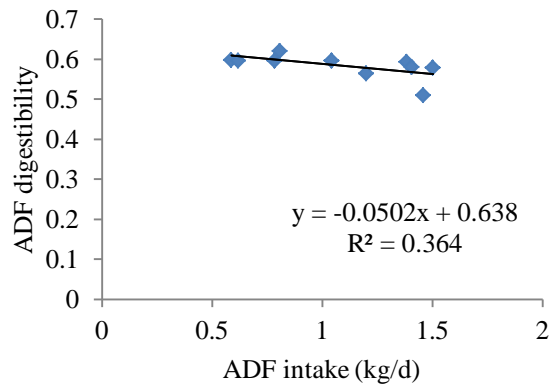
The digestibility values for the key nutrients were moderate (Table 5.5). Apparent DM digestibility was $50.1 \pm 1.8\%$ (mean \pm sd) and ranged from 47.1 to 53.5% (Table 5.5). The mean apparent digestibility of N was $60.9 \pm 2.6\%$, and ranged from 57.7 to 66.3%. Mean ADF digestibility was $58.4 \pm 2.0\%$ and ranged from 53.7 to 60.6%. Mean energy digestibility was $51.2 \pm 1.9\%$, and ranged from 47.4 to 52.8%. There were weak, negative relationships ($P < 0.05$) between constituent intakes and digestibilities for all feed constituents (Fig. 5.1).

Table 5.5. Apparent % digestibilities of dry matter (DM), crude protein (CP), acid detergent fibre (ADF) and energy (E), and concentrations of available nutrients, in the leucaena forage fed in Experiment 2

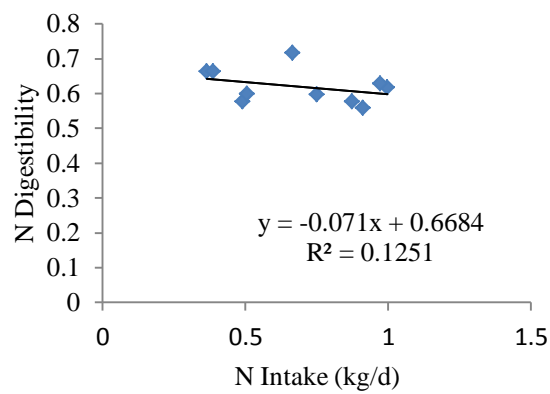
Treatment	A	A	B	B	C	C	D	D	E	E
Bull no	9	10	2	3	1	5	6	8	4	7
Constituent digestibility (%):										
DM	51.1	51.0	47.5	53.5	50.7	50.1	49.4	47.1	50.5	50.5
CP	66.3	66.2	57.7	59.8	61.7	59.6	57.7	62.8	61.7	55.9
ADF	59.8	59.6	59.7	62.1	59.7	56.5	59.3	51.0	57.8	58.1
GE	52.1	51.8	47.4	54.0	51.3	51.5	51.1	48.1	52.8	51.5
Available nutrient content (% DM basis):										
Digestible DM	51.07	50.97	47.45	53.50	50.70	50.13	49.42	47.12	50.46	50.45
Digestible CP	13.55	13.54	11.80	12.22	14.64	12.20	11.79	12.85	12.61	11.43
Digestible ADF	22.1	22.0	22.0	22.9	22.0	20.9	21.9	18.8	21.3	21.4
Available energy content (MJ/kg DM):										
DE	10.45	10.38	9.52	10.83	10.29	10.34	10.25	9.65	10.59	10.34
ME	8.47	8.41	7.71	8.77	8.34	8.37	8.30	7.82	8.58	8.37



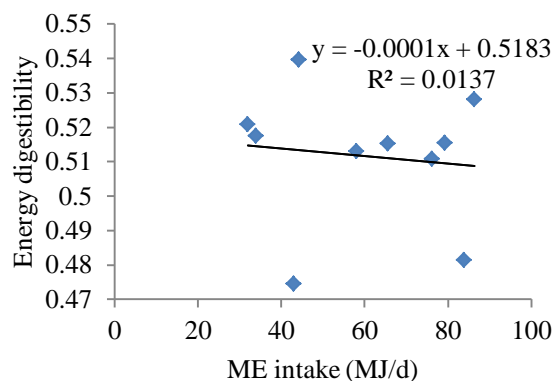
(a) *Dry matter*



(b) *Nitrogen Digestibility*



(c) *Acid detergent fibre*



(d) *Energy*

Fig. 5.1. Relationships between the intakes of dry matter, nitrogen, acid detergent fibre and energy, and the digestibilities of these constituents.

5.4.3. Feed and nutrient intake

Dry matter intakes, averaged over the whole experiment, ranged from 1614 to 4546 g per day (Table 5.6). The bulls consumed the majority of the diet offered each day. For each animal, the average daily intake calculated for the whole experiment was similar to that during the digestibility period. Intake was calculated from the daily intakes recorded for each animal throughout the whole experiment, and separately during the digestibility period.

**Table 5.6. Daily dry matter (DM) and nutrient intakes and refusals
(standard errors in brackets).**

Treatment	A	A	B	B	C	C	D	D	E	E
Bull no	9	10	2	3	1	5	6	8	4	7
Daily DM intake, whole experiment: ¹										
g	1614 (308.7)	1728 (303.7)	2205 (397.4)	2268 (391.1)	2994 (515.7)	3365 (578.7)	3885 (664.7)	4426 (780.5)	4546 (837.3)	4133 (715.2)
g/kg W ^{0.75}	49	51	58	59	79	78	98	99	117	117
% W	1.5	1.6	1.7	1.8	2.3	2.2	2.9	2.8	3.5	3.6
Daily DM intake Digestibility period: ²										
g	1592 (188.1)	1688 (200.1)	2142 (230.1)	2206 (260.7)	2894 (346.1)	3274 (392.3)	3799 (447.2)	4189 (514.6)	4307 (584.1)	3955 (462.6)
g/kg W ^{0.75}	48	49	56	57	74	74	92	92	106	107
% W	1.5	1.5	1.7	1.7	2.2	2.1	2.7	2.6	3.1	3.2
Daily nutrient intake, Digestibility period: ²										
CP (g/d)	364.7	386.6	490.5	505.2	666.2	750.0	873.0	971.4	997.5	911.4
ADF (g/d)	587.5	620.2	1045.6	809.8	1045.6	1202.8	1384.0	1384.0	1503.1	1408.9
ME (MJ/d)	13.5	14.2	16.5	19.3	24.1	27.4	31.5	32.7	36.9	33.1
Daily refusals										
DM (kg) ³	0.03	0.01	0.00	0.01	0.02	0.02	0.06	0.09	0.11	0.05
DM (kg) ⁴	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.10	0.11	0.05

¹live weights are the means of those recorded during the whole experiment

² live weights are the means of those recorded on Days 29 and 35.

³ refusals over whole experiment; ⁴ refusals in the digestibility period.

5.4.4. Liveweight change

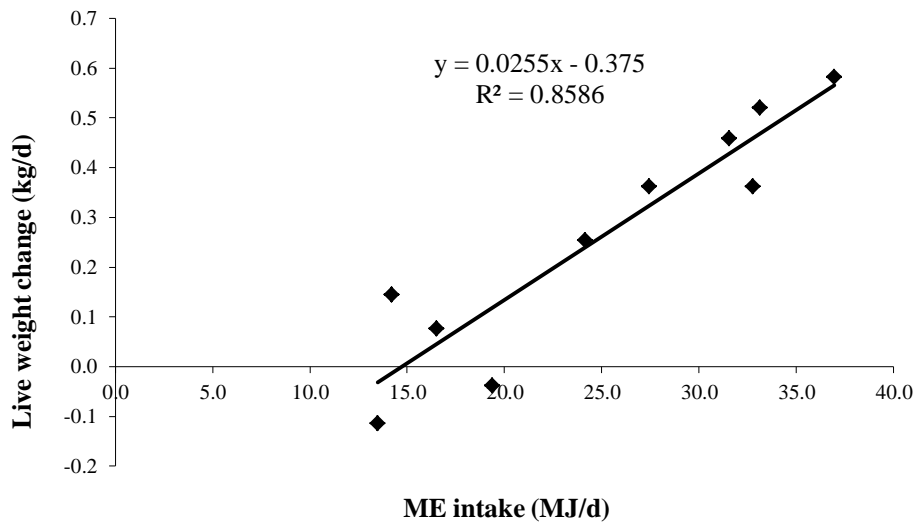
Table 5.7 shows live weight changes during Experiment 2. Weight gains of the bulls increased with the level of feeding.

Table 5.7. Liveweights, and rates of live weight changes, of Bali bulls fed varying amounts of energy

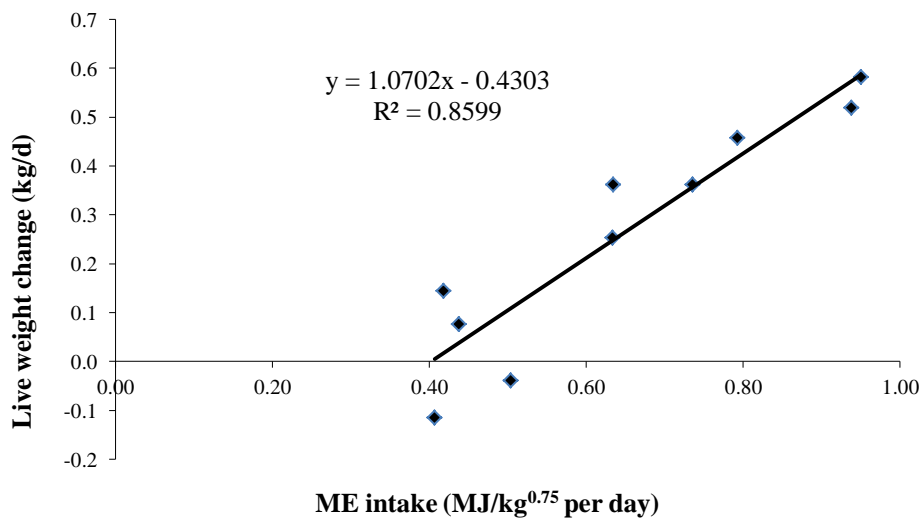
Treatment	A	A	B	B	C	C	D	D	E	E
Bull no	9	10	2	3	1	5	6	8	4	7
Elapsed days										
1	117	107.5	130	135.5	124.5	146.5	128	153.5	122.5	106.5
7	100.5	109.5	123.5	125.5	124	147	130.5	151	125.5	110.5
14	104	110	124.5	128	129	150.5	134	157.5	128	114.5
21	103.5	108.5	124	127.5	127.5	151.5	137.5	158.5	133	117
28	105.5	110	124.5	129	129.5	153	139	160.5	138	119.5
37	107.5	114.5	132.5	131	134	160.5	145	165.5	143	126.5
LWG (kg/d)	-0.11	0.14	0.08	-0.04	0.25	0.36	0.46	0.36	0.58	0.52

5.4.5. Metabolisable energy requirements for maintenance and growth

There were significant linear relationships between live weight change and ME intake in both absolute terms and on a metabolic live weight basis ($P < 0.0001$, Fig. 5.2). In both cases, the fit of the linear regression was high ($R^2 = 0.85$).



(a) Relationship between total daily ME intake and live weight change



(b) Relationship between total daily ME intake (MJ/day scaled to metabolic live weight) and live weight change (kg/d).

Figure 5. 2. Relationships between metabolisable energy intake and live weight change of Bali bulls fed a leucaena forage diet.

The regression equations (parameters \pm se) of live weight change (LWC, kg/d) on ME intake (ME, MJ/d; MJ/kgW^{0.75} per d) and their associated statistics are:

- (i) Live weight change v. total daily ME intake:

$$\text{LWC} = -0.38 (\pm 0.10) + 0.03 (\pm 0.004) \text{ ME}$$

$$(R^2 = 0.86; P < 0.0001)$$

- (ii) Live weight change v. ME scaled to metabolic size:

$$\text{LWC} = -0.43 (\pm 0.10) + 1.07 (\pm 0.15) \text{ ME}$$

$$(R^2 = 0.86; P < 0.0001)$$

These regression equations give the following estimates of the ME requirement for maintenance of male Bali cattle fed leucaena forage.

$$\text{ME}_m = 14.72 \text{ MJ/d and}$$

$$\text{ME}_m = 0.402 \text{ MJ/kgW}^{0.75} \text{ per day}$$

The ME requirement for “production” (i.e. positive live weight change of male Bali cattle under the specific conditions of this experiment) was $\text{ME}_p = 39.2$ MJ/kg live weight gain.

5.4.6. Drinking water

The average daily consumption of drinking water was recorded for each animal throughout the digestibility period (Table 5.9). Water intake was determined as drinking water and did not include water contained in feed nor account for water evaporation. Drinking water levels varied greatly between bulls, but were similar when calculated on a live weight basis (Table 5.9). The mean daily humidity recorded at Comoro during the experiment was 78% (range from 83 – 71%) while the mean daily temperature was 29.9°C (range from 28.6-31.2°C).

There was no significant relationship between drinking water intake and DM intake (Figure 5.3). The regressions (parameters) of drinking water on DM intake were:

Drinking water (L/d) = 7.74 + 0.86 DM intake (kg/d) ($R^2 = 0.33$; $P < 0.11$).

Drinking water (L/d) = 0.23 + 0.51 DMI (kg/kgW^{0.75} per d) ($R^2 = 0.11$; $P < 0.39$).

Table 5.8. Drinking water (L per d) in the digestibility period

Treatment	A	A	B	B	C	C	D	D	E	E
Bull no	9	10	2	3	1	5	6	8	4	7
L/d	9.07 (3.06)	7.46 (3.19)	8.43 (1.05)	12.56 (3.0)	17.39 (0.81)	11.15 (2.15)	11.72 (1.76)	10.80 (1.35)	10.49 (1.39)	11.33 (1.75)
L/kg BW	0.09	0.07	0.07	0.10	0.13	0.07	0.08	0.07	0.07	0.09
L/kg W ^{0.75}	0.27	0.22	0.22	0.33	0.45	0.25	0.28	0.24	0.26	0.31
L/kg DM	5.70	4.42	3.93	5.69	6.01	3.41	3.08	2.58	2.43	2.86

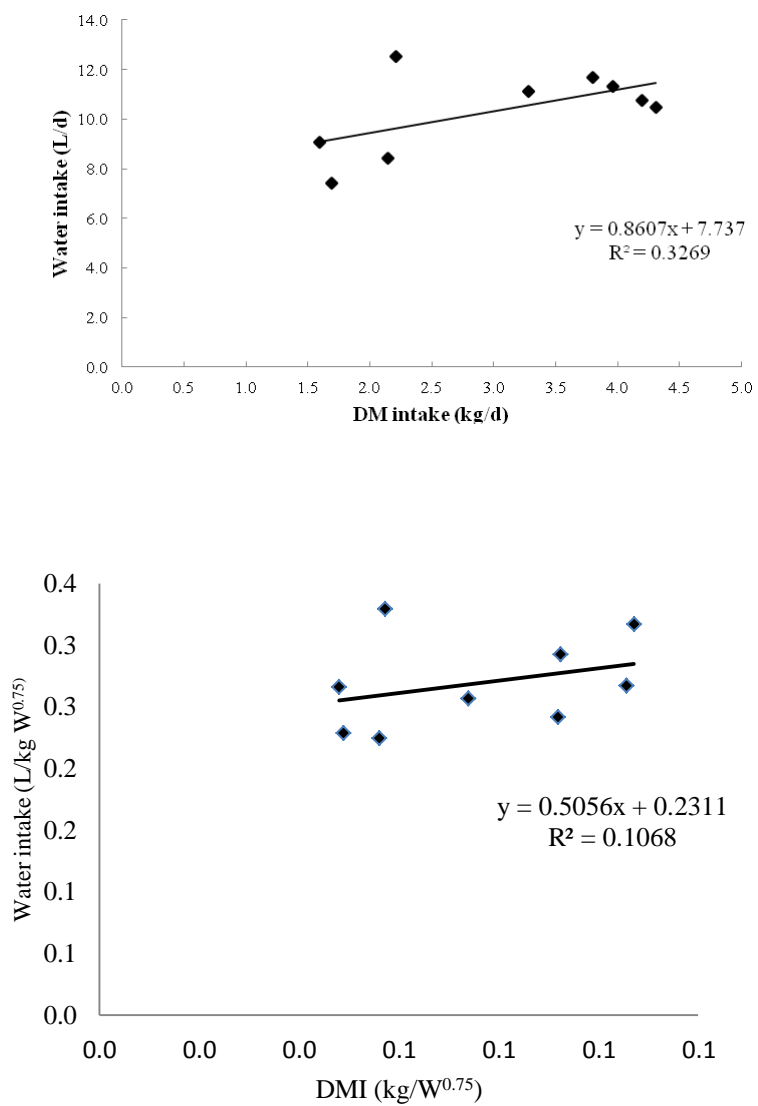


Figure 5.3 Relationship between total daily ME intake and drinking water as (a)(L/d) and (b) L/kg $W^{0.75}$ and daily DM intake (kg/ $W^{0.75}$) of Bali bulls fed a leucaena diet

5.5. Discussion

The main aims of this study were to measure the ME requirements for maintenance and production of Bali cattle fed a high-protein forage as the sole feed and to determine the level of ME required to obtain growth rates which would be acceptable to East Timorese farmers. In addition the experiment was aimed at the determination of the voluntary drinking water intake of Bali cattle fed leucaena forage, and to collect additional information on the nutritive value of leucaena fed as a sole feed to growing Bali cattle.

5.5.1. Energy requirements of male Bali cattle

5.5.1.1. Metabolisable energy requirement for maintenance

The ME requirement for maintenance measured in this experiment was 0.402 MJ/kgW^{0.75} per day. Tedeschi *et al.* (2002), in a study of the energy requirements for maintenance and growth of Nellore (a *Bos indicus* breed) bulls and steers fed high-forage diets, found that the NE_m was similar for bulls and steers, averaging 0.322 MJ/kgW^{0.75} empty body weight per day; this is approximately equivalent to 0.474 MJ ME/kg^{0.75} per day. Blaxter and Wainman (1964) worked on *Bos taurus* cattle (Aberdeen Angus steers and Ayrshire × Shorthorn steers) fed hay and flaked maize found that an improvement in the efficiency of use of ME for maintenance as the concentrate (maize) content of the ration increased.

Cardenas-Medina *et al.* (2010), in a study of energy requirements for maintenance, and the energetic efficiency of weight gain in *Bos taurus* and *Bos indicus* cows in tropical Mexico found no significant difference ($P > 0.05$) for the ME_m requirements of Zebu (*Bos indicus*) and Brown Swiss (*Bos taurus*) cows. Results for ME_m for Zebu cows (0.476 ± 0.2 MJ/kg^{0.75}/d) were within the range of values for *B. indicus* breeds. Solis *et al.* (1988) estimated 0.412 MJ/kg^{0.75} (se = 0.05) as the requirement of ME_m for Brahman cows. For Nellore cows, Calegare *et al.* (2007) estimated 0.592 MJ/kg^{0.75} for ME_m and reported 0.458, 0.454 and 0.462 MJ/kg^{0.75} for ME_m for bulls, heifers and young bulls, respectively. ME_m requirements estimated for Brown Swiss

cows (0.525 ± 0.01 MJ/kg^{0.75} per day) are similar to those reported for that type of cattle by Cardenas-Medina *et al.*, 2010.

NRC (2000) adopt a general value for the NE_m of beef cattle of 0.303 MJ/kgW^{0.75} per day, which is reduced by 10% for animals of the *Bos indicus* type and increased by 15% for entire males. For the diet used in the present experiment, this is equivalent to a ME_m of 0.468 MJ/kgW^{0.75} per day for *Bos indicus* bulls. CSIRO (2007) adopt an ME_m value of 0.373 MJ/kgW^{0.75} per day for *Bos indicus* bulls, an increase of 15% over the value recommended for steers and cows.

The results of the present study were lower than the recommendations of NRC (2000) and the results of Tedeschi *et al.* (2002), but higher than the recommendation of CSIRO (2007). They are within the published range for *Bos indicus* breeds. Differences observed in the ME_m requirements for cattle may be attributed to factors such as body composition and genetic potential for milk production, which together determine the basal energy expenditure due to the mass and activity of the metabolically active organs such as the liver and the intestines (Montaño-Bermudez *et al.* 1990; Di Costanzo 1990; Ferrell and Jenkins 1987). ME_m may vary between 10 to 30% due to genetic differences (Archer *et al.* 1999).

In this experiment it was found that the ME_m requirement of Bali cattle (*Bos javanicus*) was not substantially different to values published for either *Bos taurus* or *Bos indicus* cattle.

5.5.2. Live weight change and the metabolisable energy requirement for production.

The ME requirement for “production” in this experiment was 39.22 MJ/kg live weight gain. Garret (1980) and CSIRO (2007) discussed the relationship between energy metabolism and the amount of protein and fat deposited in growing cattle; it was found that energy requirement for growing cattle was likely to be about 8.4 to 29.3 MJ/kg body weight gain depending on the amount of fat deposited in each unit of live weight gain. The requirement could vary between animals, depending on their rate of growth, sex, stage of maturity and age. From the equation of calculation metabolisable energy requirement for production CSIRO (2007), which is claimed to be applicable to *Bos indicus* and *Bos taurus* cattle, as well as sheep, the net energy

content of the gain in this experiment is approximately 22 MJ/kg. Thus $k_p = 22/39.22 = 0.55$ for the *Leucaena* used in this experiment.

The live weight changes recorded in this experiment were positive at all levels of ME offered except for bulls no. 3 and 9. In this study the average daily live weight change was $0.26 (\pm 0.24)$ and ranged from -0.04 to 0.58 kg/d. During the dry season in West Timor, Indonesia (a similar pastoral environment to East Timor) grazing two-year-old cattle grew at 0.25 kg/d (Bamualim 1991). When the feeding system was improved by including 40% legume forage daily weight gain increased from 0.2 kg/day to 0.5 - 0.8 kg/day (Bamualim and Wirdahayati, 2003). The growth rate of grazing Ongole zebu cattle on a diet supplemented with *Leucaena* was 0.29 kg/day (Wahyuni *et al.*, 1982). Cardenas-Madina *et al.* (2010) found that zebu cows fed energy levels of 0.504, or 0.756 MJ ME/kg^{0.75}/d, or *ad libitum*, obtained live weight gains of $0.2 (\pm 0.4)$; $1.5 (\pm 3.7)$ and $0.8 (\pm 1.3)$ kg/d.

In the current study the highest live weight gain was 0.58 kg/d, which is within the range of published data (Table 5.10). The growth rates are likely to be below the highest values reported in the literature because the highest ME intakes fed in the present study were probably less than the maximum voluntary intake of *leucaena* by the Bali bulls in this experiment. The bulls in this experiment left only small amounts of feed refusals, all of which was stem, even at the highest level of ME fed. Other possible reasons for the differences between these reference data and the findings of the current study could be related to the k_m and k_g of the diets, or the nutrient content of *leucaena*, its palatability as a sole feed ingredient, and the prior experience of the animals to the feed. This nutrient content and palatability of the *leucaena*, are unlikely to have been limiting as the gross energy and N digestibility of the material used in this experiment were higher than most other published data (see below).

Table 5.9 Summary of experiments on the growth performance of Bali cattle

Author	Experimental detail	Weight gain (kg/day)
Musofie <i>et al.</i> (1982)	Bali cattle – feedlot: sugar cane tops + 0.45% <i>Leucaena</i> leaf DM	0.3
Bamualim (1991)	Bali cattle: grazing trial in the wet season	0.25
Rikka (1995)	Male Bali cattle (175-200 kg) – grazing: <i>caliandra</i> pasture under coconut	0.11
Mastika <i>et al.</i> (1996)	Bali cattle (steers) 120 kg – feedlot: 40% elephant grass + 60% concentrate (20% CP, 77% TDN)	0.76
Mastika (2003)	Bali cattle (122 kg) – feedlot – 70% elephant grass (<i>pennisetum purpureum</i>) + 30% <i>Gliricidia</i>	0.32
	Bali cattle – feedlot: 50% elephant grass+ 30% <i>Gliricidia</i> + 20 <i>Hibiscus</i> leaf	0.39
	Bali cattle – feedlot: 40% elephant grass +60% concentrate(20.74% CP, 77.3% TDN)	0.76
	Elephant grass + 4 kg concentrate (18.34% CP and 75% TDN)	0.85
Bamualim and Wirdahayati (2003)	60% grass and 40% legume leaf	0.2 – 0.8
Bamualim (1996) in Bamualim and Wirdahayati (2003)	Young Bali cattle – feedlot: 50% king grass + 37.5 <i>sesbania</i> + 12.5% <i>putak</i>	0.51

5.5.3. Drinking water intake

The requirement of cattle for drinking water is influenced by the animal's genotype, its age, physiological status, activity or productivity, food intake and food quality, and climatic conditions (Dryden 2008). The mean (\pm sd) drinking water in this experiment was 11.0 ± 1.37 L/d, and intakes ranged from 8 to 17 L per day. This result is at the lower end of the range of published water intakes for *Bos taurus* and *Bos indicus* beef cattle. Water consumptions recommended for growing beef cattle range from 15 to 67 L/d while a mature dry cow may drink about 22 to 78 L/d. These values depend greatly on animal size, DM intake, environmental conditions and the type of feed given.

Water intake is positively correlated with feed DM intake (CSIRO, 2007). The mean water: DM ratio (mean \pm sd) was 4 (\pm 1.37) L water/kg DM (range = 2.4 to 6 L water/kg DM intake) in this experiment; the mean ambient temperature ranged from 29 - 31°C. Dryden (2008) noted that animals drink about 2.5 to 4 L of water/kg of feed DM; this water/DM ratio has been reported elsewhere (Misra and Singh, 2002; Yape Kii and Dryden, 2005), but can increase in high ambient temperatures. The water intakes at 38°C of *Bos taurus* breed cattle increased to about 16 L/ kg DM eaten, and for *Bos indicus* breeds to about 10 L water/kg DM (CSIRO 2007). Water allowances for weaned *Bos taurus* cattle when measured at <15, 20, 25, 30 and 35°C were 3.5, 4, 5.5, 7.5 and 10 L/kg DMI respectively; while water allowance of *Bos indicus* at the same measurement time was lower: 3; 3.5; 4.5; 6 and 8 L/kg DMI in that order (CSIRO, 2007).

It is generally accepted that water intake is positively correlated with feed DM intake (CSIRO, 2007). Although no relationship between DM intake and drinking water was demonstrated in this experiment, this might have been because of the relatively small range in DM intakes and large individual variation in drinking water intake. The mean drinking water: DM ratio (mean \pm sd) was 4 (\pm 1.37) L/kg DM (range = 2.4 to 6 L/kg DM intake) in this experiment. Water intake from feed may account for some of the variation.

Water quality is important in maintaining water consumption; in the semi-arid zone many of the sources contain salts that will result in a high salt intake (CSIRO 2007). Water salinity has been shown to affect both water and food consumption (Dryden 2008). The water used in this experiment was from an underground source, and although its composition was probably similar to river water, this was not measured. The possible effect of salinity on the water consumption of cattle in East Timor should be investigated further.

In this experiment the leucaena diet was fibre- and protein-rich, and both of these increase the water requirement (for excreting undigested fibre and for excreting urea formed from excess protein). Ruminants tend to drink more water when they are offered feed of higher protein content (Dryden 2008). The increased water intakes were associated with higher dietary protein content when the animal has to excrete

urea produced from the deamination of excess amino acids (ARC 1980). Yape Kii and Dryden (2005) found that water consumption by rusa deer (*Cervus timorensis*) stags was influenced by different types of feed. The study found that deer consumed more water when fed oaten hay and that this was related to the higher NDF of this feed. It may be that the drinking water measured in this experiment are higher than would be expected when grass or straw was a main diet component.

To predict the drinking water intake of lot-fed beef cattle, Hicks *et al* (1988) developed an equation which included the effects of ambient conditions and DM intake:

$$W = (0.76 T) + (0.13 \text{ DMI}) - (0.66 R) - (0.29 \text{ Na/DMI}) - 6.31$$

where: W = water intake (kg/day)
 T = maximum ambient temperature (°C)
 R = rainfall (mm/day)
 DMI = food dry matter intake (kg/day)
 Na = sodium intake (g/d)

The drinking water of male Bali cattle calculated using this equation, based on the conditions prevailing in this experiment, was 15.8 L/d which is in the range of intakes (8 – 17 L/d) measured in the study. This result suggests that Bali cattle have similar drinking water requirements to other *Bos* species.

This discussion of drinking water was considered separately from the amount of water ingested from feed, and thus these results do not give the total water intake of these cattle. Total drinking water intakes ranged from 8 to 17 L per day.

5.5.4. Nutritive value of leucaena

The nutritive value of Leucaena used in this experiment was within the range of values in the published literature. The protein content of the Leucaena fed in this experiment was lower than the reference data used to formulate the ration - 21% (DM basis) compared to 25% reported by Chuzaeni and Soejono (1987) and the 25%

obtained by Gralak *et al.* (2011). However, it was higher than the 19% measured by Aregheore and Perera (2004) and 18% estimated by Aletor and Omodara (1994).

The gross energy content of the leucaena fed in this experiment was higher than the general gross energy content of forage feeds adopted by MAFF (1975), i.e. 20.1 v. 18.4 MJ/kg DM and also higher than the value, 18.2 MJ/kg DM, reported by Aregheore and Perera (2004).

The mean digestibility coefficients of the chemical constituents of leucaena used in this experiment were 50, 51, 61 and 58% respectively for DM, energy, nitrogen and acid detergent fibre. The results were similar to those reported by Bamualim *et al.* (1980) where the mean digestibility of the energy of various tropical browse legumes was 60% while Poppi and McLennan (1995) reported digestibility of energy of 63% for leucaena. Aregheore and Perera (2004) found that dry matter intake of goats fed maize stover + Leucaena was $62.3 \text{ g/kgW}^{0.75}$ per day, while digestibilities of dry matter, crude protein and energy were 66, 68 and 66%.

The ME content of the leucaena fed in this experiment where estimated used calculation of a combination of chemical analysis and prediction equations was 8.7 MJ/kg DM. This is similar to the ME content which can be calculated from the digestible DM data reported by Chuzaeni and Soejono (1987) for similar feed, although lower than ME contents which can be calculated from the data of Poppi and McLennan (1995) and Aregheore and Perera (2004). Differences in plant maturity, and in the stem:leaf ratio in the diet as fed, will contribute to variations in digestibility and ME content. Nevertheless, the values estimated in this experiment are similar to those reported by most others. An exception to this is the report of Fujihara *et al.* (2005) who reported an ME content of leucaena of 4.6 MJ/kg DM; this value seems low, and the difference between this value and that measured in the present experiment cannot be explained.

The contents of rumen-available N and bypass protein in feeds are used in modern ruminant feeding standards; nevertheless, NRC (2000) has noted that the digestibility of protein remains an important factor in feed nutritive value. However there is very limited information about any of these characteristics of protein availability for leucaena fed to cattle. Banda and Ayoade (1986) reported that supplementation of leucaena to goats given a basal diet of maize stover increased the organic matter and

crude protein digestibilities from 59% and 51% to 76% and 55%, respectively. This present study found protein digestibility was higher (60.9%) than those results. The higher apparent protein digestibility recorded in the present experiment could be explained by the leucaena used in this study having higher protein content than those used in the other studies. The leaf, seed and pod of tropical legumes are useful sources of protein to cattle during the dry season (Norman 1970), and the difference between the protein content of the leucaena forage used in this experiment and that reported by others may be due to differences in the proportions of leaf, etc. in the different samples. However, if it is subsequently shown that the protein content of leucaena grown in East Timor is consistently higher than in leucaena obtained from other tropical regions, then this would indicate that a specific East Timorese database of feed nutritive values should be prepared.

There was little evidence of a relationship between energy digestibility versus DM intake ($R^2 = 0.02$) although a reduction in DM digestibility with increased DM intake was expected. ARC (1980) reported that when intake increases, the loss of energy due to faecal excretion tends to increase due to a faster ruminal turnover, decreasing the ruminal fermentation of digestible fibre, which in turn yields less DE. In addition, the faecal loss is greater for low-quality forages than for those of high quality (Tedeschi *et al.* 2002).

Tropical plants with the C4 photosynthetic pathway have a high proportion of their protein in bundle-sheath cells which are so toughened that they afford natural protection to rapid solubilising of protein in the rumen (Brady 1976). Some tropical legumes are credited with having of their protein in a protected form. Flores *et al.* (1979) found that the total N of leaf (and fine stem) of *Leucaena leucocephala* was less soluble (21%) than Rhodes grass (32%). When Hereford weaners had access to leucaena during the winter, they gained 160 g/d compared to those without access to leucaena which lost 200 g/d; it indicated that the response due to N in Leucaena was from the less soluble or bypass protein fraction (Flores *et al.* 1979). Tannin, which occurs in *Lespedeza cuneata* and *Desmodium intortum*, apparently afforded protection to some of the protein these plants (McLeod 1974), providing by-pass protein that may be absorbed in the intestines.

The apparent digestibility of a feed is also influenced by its chemical composition; for forages the composition changes radically with the stage of maturity. Any change in the protein content must also change the relative amount of one or more of the other components. The level of protein in the feed may exert an effect on its apparent digestibility not only because of the influence of metabolic nitrogen but also because of its effect in supplying the nutrients essential for proper growth and activity of microorganisms in the rumen. The high digestibility of CP of leucaena may not only have been due to the effect of dietary CP content, but could also be due to the readily fermentable fibre content (Dutta *et al.* 1999).

Särkijärvi *et al.* (2008) found that the digestibility of silage was influenced by animal breeds. Differences in the digestibility of forages may also exist between breeds, although the literature is equivocal about this. A study estimating the ME requirement for maintenance and energetic efficiency of weight gain in *Bos taurus* and *Bos indicus* cows in tropical Mexico found that a significant difference ($P > 0.05$) in DM digestibility and gross energy digestibility due to breed, despite no effect of level of feeding (Cardenas-Medina *et al.* 2010). Other researchers have suggested that there are no differences in feed digestibility (DM and GE) between *Bos indicus* and *Bos taurus* cattle (Howes *et al.*, 1963, Kennedy 1982). Bali cattle (*B. javanicus*) are a different species to either *B. taurus* or *B. indicus*. Moore *et al.* (1975) observed a higher ($P < 0.05$) disappearance of dry matter *in vitro* in Brahman compared to Hereford (63.4 vs. 71.05 steers and this was believed to be a result of the higher rate fermentation of feedstuffs in *Bos indicus* type of cattle, due to the different rates at which rumen microorganisms attack cellulose. However, nothing has been published on the digestion kinetics of *Bos javanicus*.

Leucaena is widely used in tropical cattle production because it has a high nutrient content (especially for digestible protein) and is palatable (Jones, 1994; Wirdahayati *et al.* 2000, therefore it is a potential source of cheap protein to ruminants (Jones, 1994). However, leucaena contains anti-nutritive substances such as mimosine and tannins. The mimosine and its metabolic by-products have a sub-clinical adverse effect on ruminant animal performance (Shelton 1998). A compound called 2,3-dihydroxy-pyridine (DHP) has been found in leucaena and has been shown to be toxic (Alinson *et al.* (1990); The Future Beef. 2013); Some workers have suggested

using dried leucaena foliage as a means of reducing the effects of these anti-nutritive factors (Norton, 1994). McNeill *et al.* (1998) found that dried leucaena contains low levels of mimosine and tannins. However the likelihood was discounted in this experiment because these cattle had been previously fed leucaena was freshly harvested without apparent adverse effects, *Synergistes jonesii* (a bacterium which breaks down DHP in the rumen) was originally reported in Indonesia (Jones and Lowry, 1984) and The Leucaena Network, 2012) and was assumed to be present in East Timor given the lack of adverse effects reported for cattle fed this fodder. Metabolism of DHP is an energy-consuming process (Shelton 1998). However, the ME_m value measured in this experiment was similar to that obtained in Experiment 1 where less leucaena was fed, and also similar to values published for *Bos indicus* and *Bos taurus* cattle generally.

The present study found that fresh leucaena was suitable as a sole diet ingredient for young Bali bulls, at least for a restricted feeding period. Its use as a sole feedstuff over longer periods such as during the long dry season in East Timor (6-7 months) remains to be investigated.

In East Timor tree legumes have multiple uses in farming systems such as firewood, mulch and as an aid to soil conservation. Therefore, by knowing the beneficial effect of leucaena as a sole cattle feed, farmers would have another reason to grow leucaena alongside their crops.

Chapter 6

General Discussion and Recommendations

Overall, the metabolisable energy requirements for maintenance and production of Bali bulls are similar to those for *Bos indicus* cattle, but are lower (more than 10%) when compared to *Bos taurus* animals. Below is a discussion of these findings.

6.1. The ME requirements for maintenance and production of Bali cattle in East Timor

In this study two equations were produced to predict the ME requirements of Bali cattle in East Timor according to the quality of diet offered. These are:

1. Equation to calculate the ME requirements of Bali cattle in East Timor given low-quality feed:

Live weight change (LWC, kg/d) v. ME intake scaled to metabolic size (ME_{met} , MJ/kgW^{0.75} per d):

$$LWC = -0.79 (\pm 0.11) + 1.89 (\pm 0.37) ME_{met}$$

The ME requirement for maintenance is 0.42 MJ/kgW^{0.75} per day.

2. Equation to calculate the ME requirements of Bali cattle in East Timor given moderate- quality feed:

Live weight change (LWC, kg/d) v. ME intake scaled to metabolic size (ME_{met} , MJ/kgW^{0.75} per d):

$$LWC = -0.40 (\pm 0.10) + 1.07 (\pm 0.15) ME_{met}$$

The ME requirement for maintenance is 0.402 MJ/kgW^{0.75} per day.

The ME requirement for maintenance (ME_m) of Bali cattle was calculated to be 0.42 and 0.43 MJ/kgW^{0.75} per day (Table 6.1). If the CSIRO (2007) formula for estimating the efficiency of use of ME for maintenance (k_m) is applied to these data, the estimated k_m (Table 6.1) give an estimate of the net energy maintenance requirement (NE_m) of 0.26 MJ/kgW^{0.75} per day.

Table 6.1. A comparison of the metabolisable energy (ME) requirements and efficiencies of ME use for maintenance and production (k_m , k_p and k_g) in Experiment 1 and Experiment 2

Parameter	Experiment 1	Experiment 2
Diet ME content (MJ/kg DM)	5.54	8.74
Energy requirement for maintenance		
Metabolisable energy (MJ/kg $W^{0.75}$ per d)	0.42	0.40
k_m ¹	0.61	0.67
Net energy (MJ/kg $W^{0.75}$ per d)	0.256	0.266
Energy requirement for live weight change (ME_p , MJ/kg LWC)		39.2
Net energy content of live weight gain (MJ/kg) ²		13.33
k_p		0.34

¹ calculated from the diet ME content, based on CSIRO (2007)

² the estimated net energy content of live weight gain was calculated using the CSIRO (2007) equation:

$$EVG \text{ (MJ/kg LWG)} = (6.7 + (L - 2)) + (20.3 - (L - 2)) / (1 + \exp(-6 \cdot (Z - 0.4)))$$

where: EVG is the net energy content of live weight gain; L is the feeding level, which is the ME intake in multiples of the maintenance requirement; and Z is the ratio of current live weight to expected mature live weight. This equation was adopted by CSIRO (2007) for “all breeds of cattle including *Bos indicus*”.

The expected mature weight of Bali bulls is about 415 kg (337 to 494 kg) (Pane, 1991); the average weight of the bulls in Experiment 1 was 121 kg, and 129 kg in Experiment 2. Thus Z in the above equation is $129/415 = 0.31$ for the “average” animal in Experiment 2. The ME requirement for “production” (i.e. positive live weight change of male Bali cattle given a moderate-quality feed) was 39.2 MJ/kg live weight gain in Experiment 2. By assuming a net energy content of gain of 13.33 MJ/kg (calculated from the CSIRO equation), this result gives an efficiency of use of dietary ME for growth of 0.34, for Bali bulls fed a moderate-quality diet. When the

amount of ME_m is adjusted for efficiency of ME use, the net energy requirement for maintenance becomes almost the same in the two experiments.

In Experiment 1, where the bulls were fed a low-quality feed, the ME_m was slightly higher than in Experiment 2 (0.42 versus 0.40 MJ/kgW^{0.75} per d). The differences in these values could be due to the lower k_m expected in Experiment 1 because of the poorer quality feed.

Firstly, the lower ME_m in Experiment 1 could be explained by the expected lower k_m in that experiments (0.61 in Experiment 1 versus 0.67 in Experiment 2). The efficiency of ME use for maintenance is related to the source of the ME (Garret, 1980). The feed used in Experiment 1 was of poor quality and had a high fibre content. Webster *et al* (1976) indicated that the efficiency of ME use declines as food becomes more fibrous, and this trend is reflected in the CSIRO (2007) equation to predict k_m .

The values for k_m estimated from the CSIRO (2007) equation are likely to apply to Bali cattle because the evidence suggests that there are no between-breed differences in k_m . Chizotti *et al.* (2007), in a study of the energy requirements for growth and maintenance of F1 Nellore \times Red Angus bulls, steers and heifers which were fed corn silage (75%) and a concentrate mixture containing cracked corn grain and soybean meal (25%), found that the k_m was not significantly different among groups (i.e. steers, bulls and heifers) ($P < 0.24$) and averaged 0.71. Tedeschi *et al.* (2002) observed that the k_m for bulls fed high-forage diets was 0.64. Ferrell and Jenkins (1985) in a study of body composition and energy utilization by steers of diverse genotypes fed a high concentrate diet during the finishing period found similar values of k_m , ranging from 0.65 to 0.69. Cardenas-Medina *et al* (2010) estimated the ME_m and the energetic efficiency of weight gain (k_g) in *Bos taurus* and *Bos indicus* cows in tropical Mexico fed three levels of ME. They found that there were no significant differences ($P > 0.05$) in k_m between *Bos indicus* and *Bos taurus* cattle (0.62 and 0.74 respectively).

It is important to recognise the importance of the efficiency of energy use at near- or under- maintenance conditions to cattle production in East Timor, where for several months each year the feed available to grazing cattle provides only a maintenance or sub-maintenance ration. Frisch and Vercoe (1984) found that breeds such as the *Bos indicus* were likely to have evolved in a poor nutritional environment, and would have been automatically selected for low ME_m (good survival ability). However, a

consequence of this adaptation is a comparatively low growth rate under good nutritional conditions. The good survival ability of Bali cattle (*Bos javanicus*) under poor nutritional conditions (Talib *et al.* 2003) would be consistent with this hypothesis.

Because almost all the bulls in Experiment 1 lost weight, the ME requirement for growth could not be calculated in that experiment. However, in Experiment 2 with moderate-quality forage (20.45 vs. 10.8% CP and 8.74 vs. 5.54 MJ ME/kg DM, for the feeds used in Experiments 1 and 2 respectively), all of the bulls showed positive growth.

The ME required for live weight gain (ME_p) in Experiment 2 was 39.2 MJ/kg while the efficiency for growth (k_p) was 0.34. The k_p value is the net efficiency of use of ME for live weight gain, i.e. mainly for protein and fat synthesis (Garret 1980; CSIRO 2007). The lower ME_m in Experiment 2 on the basis of the better quality feed that used; this feed would be associated with a high k_m , and thus a lower ME_m (Note that $ME_m = NE_m/k_m$).

Garret (1980) noted that the ME required for live weight gain (ME_g) depends on the NE content of the gain which, in turn, depends on its fat and protein contents – the more fat, the higher the NE content. ME_g also depends on the efficiency with which dietary ME is used for growth (k_g). The k_g reported by Chizotti *et al.* (2007) in the study referred to above were not significantly different among groups (i.e. steers, bulls and heifers). A k_p of 0.34 was calculated in Experiment 2, This value is very similar to that predicted by CSIRO (2007) equation 1.35 from the diet ME content, and is also similar to the k_g of 0.39 for bulls fed high-forage diets reported by Tedeschi *et al.* (2002).

Another issue that may affect the estimate of k_g is error in the estimation of the ME_m requirement (ARC 1980). Experiment 2 was conducted over a 4-week growing period; and a longer period could have given a different result.

6.2. Predicted requirements for energy (maintenance and production) and feed of Bali cattle fed different feeds in East Timor

Based on the equations derived from the present experiments the calculated ME requirements for maintenance and production, and recommended feeding levels for production, are as in Tables 6.2 and 6.3.

Because the ME and DM contents of feeds vary from one batch to another, the calculations in these tables were based on several assumptions:

1. The EVG was calculated based on CSIRO (2007) equation with L (= ME intake/ ME_m) taken to be 1.4 and the mature live weight of Bali cattle was taken to be 416 kg (Pane, 1991).
2. For Table 6.2 (low-quality feed) $ME_m = 0.42 \text{ MJ/kg } W^{0.75}$; ME content of feed = 5.54 MJ/kg DM; feed DM content = 80%; and estimated $k_g = 0.25$ (from CSIRO 2007).
3. For Table 6.3 (moderate-quality feed) $ME_m = 0.4 \text{ MJ/kg } W^{0.75}$; ME content of feed = 8.74 MJ/kg DM, feed DM content = 80%; and $k_g = 0.37$.

Church (1977) suggested that the maximum daily DM intake for ruminants is equivalent to approximately 2.7% of live weight. In both experiments the daily DM intake of some bulls was more than 2.7% of their live weight. This study indicated that Bali cattle can eat an amount of DM equivalent to about 4% of live weight daily, therefore the DM intakes shown in italics in Table 6.2 and 6.3, which are higher than the Church (1977) recommendation, may be able to be eaten. The result suggests that Bali cattle may have adapted to low-quality nutritional environments. However, the use of low-quality feeds for young Bali cattle (as in Experiment 1) is not recommended, especially if high growth rates are required.

Intake can become an issue with lower quality forages. Ellis et al. (2004) found that differences between diets in eating rate were related to differences in both quality and quantity of available feed; eating rate was higher on good quality than low quality hay. Feed palatability may also affect nutrient intake. Feed selection depends on palatability and the latter depends on both plant and animal factors (Ngwa *et al.* 2003). Marten (1978) noted that the palatability of plants was influenced by intra-specific variation in chemical composition, morphology or physical traits, succulence and

maturation. Phenolics, alkaloids, tannins and aromatic compounds are some of the chemical compounds known to alter palatability and intake (Marten (1978).

For a number of tropical forage species, including *Chloris gayana*, *Panicum* spp (Minson 1967) and legume species (Stobbs 1971) the level of voluntary feed intake has been shown to decrease with decreased digestibility, compounding, rather than compensating for, the effects of an inadequate diet.

Table 6.2. Energy requirements for maintenance and production of Bali cattle fed a low-quality roughage-based diet in East Timor

Animal live weight (kg)	Growth rate (kg/d)	ME requirement for maintenance (MJ/d)	ME requirement for growth (MJ/d)	Total ME requirement for growing animal (MJ/d)	Total DM requirement for growing animal (kg/d)*	Total feed (as-fed) requirement for growing animal (kg/d)
50	0.00	7.90	0.00	7.90	<i>1.43</i>	1.78
	0.10		3.75	11.65	<i>2.10</i>	2.63
	0.20		7.51	15.41	<i>2.78</i>	3.48
	0.30		11.26	19.16	<i>3.46</i>	4.32
	0.40		15.02	22.92	<i>4.14</i>	5.17
	0.50		18.77	26.67	<i>4.81</i>	6.02
	0.60		22.53	30.42	<i>5.49</i>	6.86
100	0.00	13.28	0.00	13.28	2.40	3.00
	0.10		4.76	18.04	<i>3.26</i>	4.07
	0.20		9.52	22.80	<i>4.12</i>	5.14
	0.30		14.28	27.56	<i>4.97</i>	6.22
	0.40		19.03	32.32	<i>5.83</i>	7.29
	0.50		23.79	37.07	<i>6.69</i>	8.37
	0.60		28.55	41.83	<i>7.55</i>	9.44
150	0.00	18.00	0.00	18.00	3.25	4.06
	0.10		6.13	24.13	<i>4.36</i>	5.44
	0.20		12.26	30.26	<i>5.46</i>	6.83
	0.30		18.38	36.39	<i>6.57</i>	8.21
	0.40		24.51	42.51	<i>7.67</i>	9.59
	0.50		30.64	48.64	<i>8.78</i>	10.98
	0.60		36.77	54.77	<i>9.89</i>	12.36
200	0.00	22.34	0.00	22.34	4.03	5.04
	0.10		7.61	29.95	<i>5.41</i>	6.76
	0.20		15.23	37.56	<i>6.78</i>	8.48
	0.30		22.84	45.18	<i>8.15</i>	10.19
	0.40		30.45	52.79	<i>9.53</i>	11.91
	0.50		38.07	60.40	<i>10.90</i>	13.63
	0.60		45.68	68.02	<i>12.28</i>	15.35
250	0.00	26.41	0.00	26.41	4.77	5.96
	0.10		8.87	35.28	<i>6.37</i>	7.96
	0.20		17.75	44.15	<i>7.97</i>	9.96
	0.30		26.62	53.03	<i>9.57</i>	11.96
	0.40		35.49	61.90	<i>11.17</i>	13.97
	0.50		44.37	70.77	<i>12.77</i>	15.97
	0.60		53.24	79.65	<i>14.38</i>	17.97

Table 6.2 (continued)

300	0.00	30.28	0.00	30.28	5.46	6.83
	0.10		9.74	40.01	7.22	9.03
	0.20		19.48	49.75	8.98	11.23
	0.30		29.21	59.49	<i>10.74</i>	13.42
	0.40		38.95	69.23	<i>12.50</i>	15.62
	0.50		48.69	78.96	<i>14.25</i>	17.82
	0.60		58.43	88.70	<i>16.01</i>	20.01
350	0.00	33.99	0.00	33.99	6.13	7.67
	0.10		10.25	44.23	7.98	9.98
	0.20		20.49	54.48	9.83	12.29
	0.30		30.74	64.73	<i>11.68</i>	14.60
	0.40		40.99	74.98	<i>13.53</i>	16.92
	0.50		51.24	85.22	<i>15.38</i>	19.23
	0.60		61.48	95.47	<i>17.23</i>	21.54
400	0.00	37.57	0.00	37.57	6.78	8.48
	0.10		10.52	48.09	8.68	10.85
	0.20		21.04	58.61	10.58	13.22
	0.30		31.57	69.13	<i>12.48</i>	15.60
	0.40		42.09	79.65	<i>14.38</i>	17.97
	0.50		52.61	90.18	<i>16.28</i>	20.35
	0.60		63.13	100.70	<i>18.18</i>	22.72

*The DM intakes indicated in italics are greater than intakes equivalent to 2.7% of animal live weight per day.

Table 6.3. Energy requirements for maintenance and production of Bali cattle fed a moderate-quality roughage-based diet in East Timor

Animal live weight (kg)	Growth rate (kg/d)	ME requirement for maintenance (MJ/d)	ME requirement for growth (MJ/d)	Total ME requirement for growing animal (MJ/d)	Total DM requirement for growing animal (kg/d)*	Total feed (as-fed) requirement for growing animal (kg/d)
50	0.00	7.56	0.00	7.56	0.86	1.63
	0.10		2.52	10.08	1.15	2.17
	0.20		5.03	12.59	1.44	2.71
	0.30		7.55	15.11	1.73	3.26
	0.40		10.07	17.62	2.02	3.80
	0.50		12.58	20.14	2.30	4.34
	0.60		15.10	22.66	2.59	4.88
100	0.00	12.71	0.00	12.71	1.45	2.74
	0.10		3.19	15.90	1.82	3.43
	0.20		6.38	19.09	2.18	4.11
	0.30		9.57	22.28	2.55	4.80
	0.40		12.76	25.47	2.91	5.49
	0.50		15.95	28.66	3.28	6.18
	0.60		19.14	31.85	3.64	6.86
150	0.00	17.23	0.00	17.23	1.97	3.71
	0.10		4.11	21.34	2.44	4.60
	0.20		8.21	25.44	2.91	5.48
	0.30		12.32	29.55	3.38	6.37
	0.40		16.43	33.66	3.85	7.25
	0.50		20.54	37.77	4.32	8.14
	0.60		24.64	41.87	4.79	9.02
200	0.00	21.38	0.00	21.38	2.45	4.61
	0.10		5.10	26.48	3.03	5.71
	0.20		10.21	31.59	3.61	6.81
	0.30		15.31	36.69	4.20	7.91
	0.40		20.41	41.79	4.78	9.01
	0.50		25.51	46.89	5.37	10.11
	0.60		30.62	52.00	5.95	11.21
250	0.00	25.27	0.00	25.27	2.89	5.45
	0.10		5.95	31.22	3.57	6.73
	0.20		11.89	37.17	4.25	8.01
	0.30		17.84	43.12	4.93	9.29
	0.40		23.79	49.06	5.61	10.57
	0.50		29.74	55.01	6.29	11.86
	0.60		35.68	60.96	6.97	13.14

Table 6.3 (continued)

300	0.00	28.98	0.00	28.98	3.32	6.25
	0.10		6.53	35.50	4.06	7.65
	0.20		13.05	42.03	4.81	9.06
	0.30		19.58	48.56	5.56	10.46
	0.40		26.11	55.08	6.30	11.87
	0.50		32.63	61.61	7.05	13.28
	0.60		39.16	68.14	7.80	14.68
350	0.00	32.53	0.00	32.53	3.72	7.01
	0.10		6.87	39.40	4.51	8.49
	0.20		13.74	46.27	5.29	9.97
	0.30		20.60	53.13	6.08	11.45
	0.40		27.47	60.00	6.87	12.93
	0.50		34.34	66.87	7.65	14.41
	0.60		41.21	73.74	8.44	15.89
400	0.00	35.96	0.00	35.96	4.11	7.75
	0.10		7.05	43.01	4.92	9.27
	0.20		14.10	50.06	5.73	10.79
	0.30		21.16	57.11	6.53	12.31
	0.40		28.21	64.16	7.34	13.83
	0.50		35.26	71.22	8.15	15.35
	0.60		42.31	78.27	8.96	16.87

*The DM intakes indicated in italics are greater than intakes equivalent to 2.7% of animal live weight per d.

6.3. Feed information relevant to East Timor

Feed constituent digestibilities in Experiment 2 were higher than in Experiment 1. In Experiment 1 the bulls were fed a mixed urea-treated rice straw and leucaena diet. The digestibility of DM in the urea-treated rice straw, estimated by the “digestibility by difference” method described by Schneider and Flatt (1975), was 25%; resulting in a low overall digestibility of the diet fed in Experiment 1.

Table 6.4. A comparison of average of feed constituent digestibilities in Experiment 1 and Experiment 2 (standard deviation in brackets)

Parameter	Experiment 1	Experiment 2
Digestibility (%):		
DM	33.7 (8.47)	50.1 (1.8)
CP	30.7 (6.23)	60.9 (3.0)
ADF	19.1 (5.14)	58.4 (2.0)
GE	37.5 (5.14)	51.2 (1.9)

Dryden (2008) noted that digestibility is greatly influenced by the physico-chemical composition of the food. The lignified fibre component of forage can limit ruminal microbial degradation and total digestibility (Fonseca *et al.* 1998) and the digestibilities of carbohydrate and proteins may be restricted by plant tannins. Rice straw is rich in lignin and silica (Shen *et al.* 1998). The silica has a function of increasing the degree of resistance against plant pathogens and against lodging of the plants (Deren *et al.*, 1994 and Shen *et al.* 1998).

Digestibility is affected by the botanical composition and stage of maturity of the forage and also by processing and chemical treatment (Miller, 1961). Carbohydrates are either non-structural (readily digested by all livestock) or structural (some are digested through fermentation that occurs in the rumen). As plant mature, cell walls become more lignified and less digestible. Forage digestibility declines greatly if forages become over-mature before cutting or grazing. High ambient temperatures tend to increase plant lignification, thus lowering the digestibility of forages.

The diet used in Experiment 1 contained more fibre compared to the sole leucaena diet fed in Experiment 2. This may explain some of the difference in ration digestibility found in the two

experiments. Based on feed recommendations Table 6.2 indicates that rice straw in East Timor is may be suitable in particular for young animals.

6.4. Drinking water intake

The voluntary drinking water intake of Bali cattle fed protein- and fibre-rich feeds can be predicted from the equations below:

$$\text{Drinking water (L/d)} = 7.74 + 0.86 \text{ DM intake (kg/d) or}$$

$$\text{Drinking water (L/d)} = 0.23 + 0.51 \text{ DM intake (kg/kgW}^{0.75} \text{ per d)}$$

The mean (\pm sd) drinking water in this experiment was 11.0 ± 1.37 L/d, and intakes ranged from 8 to 17 L per day. The mean drinking water: DM ratio (mean \pm sd) was $4 (\pm 1.37)$ L water/kg DM (range = 2.4 to 6 L water/kg DM intake), when the mean ambient temperature ranged from 29 - 31°C.

It should be noted that these values relate to the intake of drinking water, not the total water intake. Beef cattle are commonly managed under intensive conditions (e.g. in pens or small paddocks with cut-and-carry feeding) where owners have to provide drinking water in troughs, and so estimates of the drinking water requirements of Bali cattle in East Timor are relevant to cattle management in that country. Drinking water intakes of Bali bulls fed leucaena under the weather conditions prevailing in the mid-dry season in East Timor were similar to that expected for other cattle breeds and could be calculated from the general equation of Hicks *et al.* (1998). This result suggests that Bali cattle have similar water requirements to other *Bos* species.

6.5. Conclusions and recommendations

The main problem for animal production in East Timor is insufficiency of high-quality feed over the whole year. Cattle feeding systems practised by East Timorese farmers are influenced by socio-cultural factors. These two factors determine the animals' nutritional environment, and thus their productivity.

The mixed-farming practiced in East Timor may often lead to farmers having insufficient time to prepare adequate feeds for their livestock. Hence, the quantity and timing of feeding and watering are determined by time and resource constraints rather than the animals' requirements. Consequently, Bali cattle in East Timor tend to be reared under poor

management which results in under-feeding or feeding on feeds of low nutritive value. However, about 60% of Bali cattle are either completely hand fed or are given some additional feed (Salsinha *at al.* 2008). This means that a majority of East Timorese cattle are managed in a way that would easily allow the application of the type of information which has been obtained in the two experiments described in this thesis.

To obtain a sufficient energy requirement for maintenance and production of Bali bulls it is recommended that the diets should be at least of sufficient ME content to provide 0.42 MJ/kg $\text{MJ/kgW}^{0.75}$ per d and 39.2 MJ/kg live weight gain. The feeding recommendations in Tables 6.2 and 6.3 should meet these requirements.

It is recommended that ME requirements are measured, using an approach similar to the one used in this experiment, for Bali cattle given other feeds typical of those used in East Timor. Based on the discussion above it is recommended to measure ME_m and ME_p for specific feeds used in East Timor to feed cattle due to the fact that k_m and k_g are heavily influenced by feed type, especially the ME content.

The ME_m of Bali cattle is similar to *Bos indicus* breeds, and thus we can use the ARC or NRC or CSIRO feeding standards for these cattle.

The water requirements of Bali cattle are unknown, except for the data reported here. It is recommended that further investigations be undertaken into the water intakes of Bali cattle, especially when fed other feeds are used in East Timor, so as to obtain a more reliable estimate of these requirements. Knowledge of water requirement is very important due to the limited availability of water during the dry season, and because water must usually be carted by hand to supply penned or tethered animals.

The results of this experiment suggest that leucaena can be used as a single diet component for Bali cattle for a short period. As leucaena is widely available in East Timor, and is cheap and affordable by most farmers, its use as a dry season feed for growing cattle should be further explored.

The current study was conducted with Bali bulls. It is recommended that if these results are to be applied to Bali cows, older animals, or animals in a different physiological state, then further work should be done to establish the applicability of these results. Also, many dietary and environmental factors influence the ME requirements for maintenance and production; in particular, feed nutritive value, diet type, age and weather. These need to be considered when calculating the ME requirements of Bali cattle.

Water may become scarce, especially in the dry season, therefore farmers may not be able to meet the needs of their animals. Sufficient drinking water should be available all the time for Bali cattle. This is especially so in the dry season when feeds contain less water and surface water availability is limited.

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